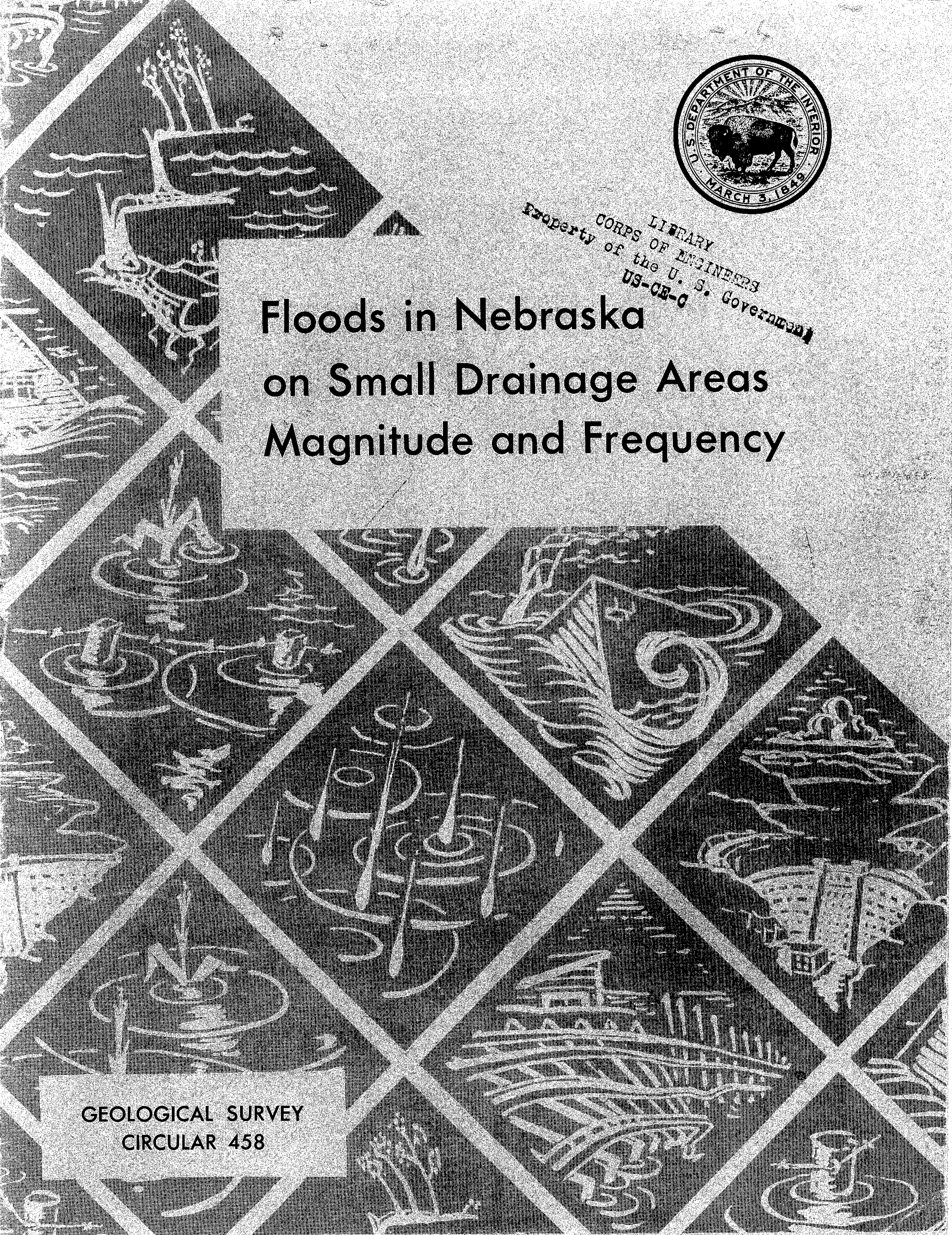

Floods in Nebraska on Small Drainage Areas Magnitude and Frequency

GEOLOGICAL SURVEY
CIRCULAR 458

PREPARED IN COOPERATION WITH THE NEBRASKA DEPARTMENT OF ROADS

Floods in Nebraska on Small Drainage Areas, Magnitude and Frequency

By Emil W. Beckman and Norman E. Hutchison

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CONTENTS

ILLUSTRATIONS

TABLES

Floods in Nebraska on Small Drainage Areas, Magnitude and Frequency

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ABSTRACT

Flood hazard information is needed for small streams as well as for large ones. This report explains methods of defining the magnitude and frequency of floods in Nebraska on uncontrolled and unregulated streams which have about 300 square miles or less of drainage area contributing to surface runoff. Composite frequency curves defined for two flood regions express a ratio of floods with recurrence intervals ranging from 1.1 to 25 years to the mean annual flood. Curves for 10 hydrologic areas were defined to show the relation of the mean annual flood to the contributing drainage area. A flood-frequency curve can be drawn from these two sets of curves for any site in the State within the range of drainage area and recurrence interval that is defined by the base data and not materially affected by the works of man. The two sets of curves are based on all available pertinent data from records of 5 or more years' duration.

This report includes a tabulation of maximum flood peaks at gaging stations used and at a number of miscellaneous sites which have less than 300 square miles of contributing drainage area.

INTRODUCTION

When loss of life is not a factor, it is generally not economically sound to design structures in or across streams for the maximum flood that may occur. Economic considerations will dictate the choice of a design frequency. An evaluation of these economic factors is beyond the scope of this report. It should be noted that the recurrence interval of a flood does not imply any regularity of occurrence. For an example, at any site, two 25-year floods may occur in consecutive weeks or such a flood may not occur in a period of 50 years.

The purpose of this report is to describe methods by which the magnitude and frequency of floods may be determined for most sites in Nebraska for which the drainage area is less than 300 square miles. The report was prepared in the Lincoln office of the U.S. Geological Survey, under the direction of Floyd F. LeFever, district engineer, Surface Water Branch, in cooperation with the Nebraska Department of Roads. Financial assistance in the preparation of the report was given by the Bureau of Public Roads.

DESCRIPTION OF AREA

PHYSIOGRAPHY

Nebraska has an expansive, gently rolling to rough topography, broken in places by low hills, a few isolated buttes, mesas, ravines, and several relatively shallow, major streams which flow in an easterly direction.

The altitude of the State ranges from 835 feet at the extreme southeast corner to a maximum of 5,340 feet at the western border. The land surface slopes rather consistently to the southeast with an average decline of about 9 feet per mile.

The small streams of Nebraska have a wide variation in slope depending on the topography of their drainage basins. The average fall for individual streams used in this report ranges from about 6 to about 110 feet per mile. The major streams fall from 4 to 8 feet per mile.

SOIL

Most of the soil mantle of Nebraska originated from four major sources. The general location of these soils is shown on figure 1, which is based on reports by the Nebraska State Planning Board (1941), by Condra (1920), and by Jenkins and others (1946), and was used by Furness (1955).

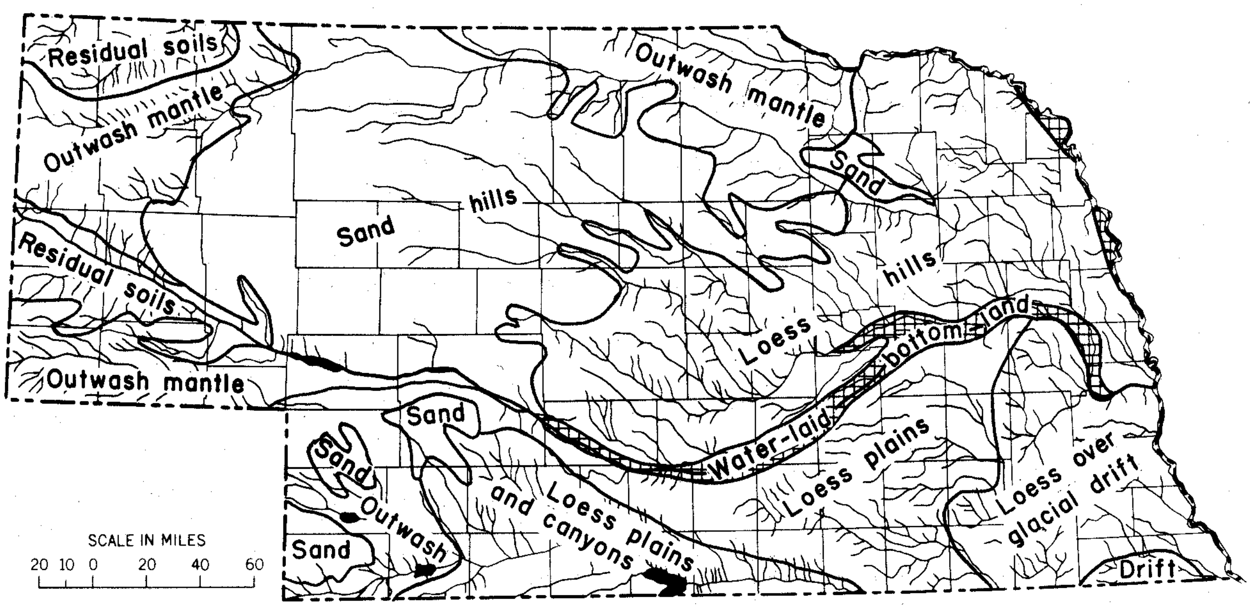


Figure 1. —Generalized areas of soil sources in Nebraska.

Loess silt is the predominant mantle of Nebraska. It is wind transported from both glacial deposits and mountain outwash and is quite uniform in texture but decreases in grain size toward the southeast. It erodes readily when on a steep gradient and usually with a vertical cleavage line. Except for scattered land-locked areas in the headwaters of streams draining relatively level areas of the south-central plains, the drainage patterns are connected and runoff is prompt.

The Sand Hill region, second in areal extent of the four major soil areas, is composed mostly of porous dune sand formed from the weathering and reworking of sandy bedrock and early water and glacial deposits of sand and gravel. Except in the immediate vicinity of the few primary channels, there is no drainage pattern or surface connections to the streams. Rainfall readily reaches the high ground-water table and forms numerous lakes and marshes. Sand Hill streams have a fairly uniform flow which originates from the ground-water table. Flood runoff is minor and comes primarily from the narrow strips of land immediately adjoining the streams.

The outwash mantle from the mountains to the west and northwest is found in several areas along the western and northern parts of the State. The original high-plains surface remains as a variety of topographic forms ranging from comparatively smooth to rolling, as deeply eroded canyons, and as rough broken areas. The soil varies widely in texture. The drainage pattern is generally well defined and runoff is prompt although the slope of each drainage basin is an influencing factor.

Residual soils, the least in areal extent formed in place from sedimentary rocks and are found primarily in several smaller areas of western Nebraska. The ground surface varies from nearly level to undulating, rolling, rough and mountainous. Sedimentary rocks are exposed in the rough badlands. The soil texture also has a wide range in the residual soil areas. The drainage pattern is well defined and runoff is quite prompt.

Water-laid bottom land and areas of glacial drift are exposed to a very limited extent in the State.

CLIMATE

The climate of Nebraska is typical of large interior continental areas in the middle latitude; it is characterized by light average annual precipitation, a great range of precipitation from season to season and year to year, and frequent and abrupt changes in temperature and other weather conditions.

The average annual rainfall shows a gradual progressive increase from 14 inches in the extreme western part of the State to 34 inches in the southeastern corner. About 75 percent of the annual precipitation falls during the six-month period April through September and about 42 percent of the annual precipitation falls in May, June, and July. A large part of the summer rainfall occurs during thunderstorms and generally falls at intense rates in short periods of time.

DRAINAGE AREAS

The total drainage area of streams in a major part of Nebraska does not contribute to the surface runoff; therefore, it is necessary to determine both the total drainage area and the area which contributes to the stream by surface runoff. Both total and contributing drainage areas are shown for the stations used; however, owing to the lack of complete coverage of good topographic maps of the State, some of the drainage area figures are qualified as approximate. Some of the small drainage areas were determined from aerial-survey photographs obtained from the U.S. Department of Agriculture, Commodity Stabilization Service.

Nebraska is completely mapped by 1:250,000-scale maps of either 50-foot or 100-foot contour intervals. The scale and contour intervals do not permit reliable determination of drainage areas, especially for smaller, fairly level areas or, differentiation between contributing and noncontributing drainage areas.

Topographic maps, in scales varying from 1:24,000 to 1:125,000 and with contour intervals varying from 5 to 20 feet, have been published for about two-thirds of the State.

CAUSES OF FLOODS

In Nebraska the annual floods on drainage areas of less than 300 square miles generally occur during the months April through September. There are some spring breakup floods; they occur most frequently in the Sand Hill region where there is a relatively limited range in discharge.

Rainfall is the primary cause of floods. Much of the rainfall results from thunderstorms and ranges widely in amount, intensity, and distribution, so that the relation of the actual amount of rainfall to the flood peak cannot be correlated. Besides the stream basins physiography which is fairly stable, the following conditions also influence the size of floods: (1) antecedent conditions, (2) direction of the storm, (3) variation of soil infiltration rate, and (4) land use and vegetal cover.

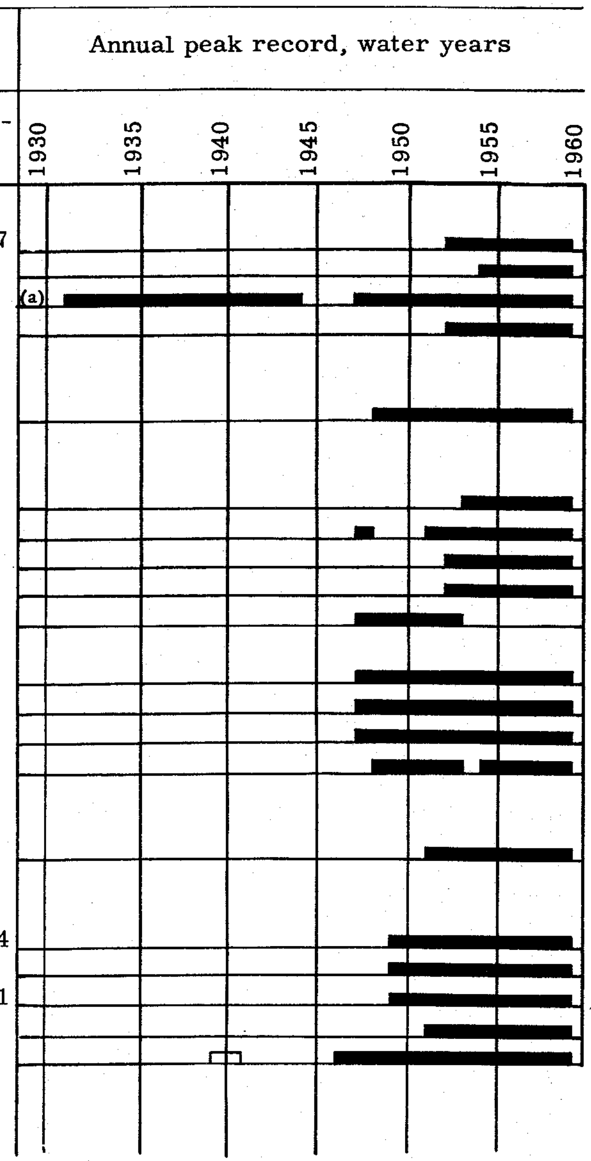
FLOOD RECORDS AVAILABLE

Records for 5 or more years in length of the annual floods not materially affected by regulation and diversion are available for 136 stations in Nebraska which have 300 square miles or less in contributing drainage area. In addition, six stations which have more than 300 square miles of contributing drainage area are included because of their strategic location. These six stations are: White River at Crawford, Ponca Creek at Anoka, Plum Creek near Meadville, Long Pine Creek near Riverview, Bazile Creek near Niobrara and Wood River near Riverdale. Table 1 gives a list, in the downstream order, of the stations used, their drainage area size, and a graphical illustration of the length of record of annual peaks. Of the total of 142 stations, 83 are crest-stage gages, most of which are operated in cooperation with the Nebraska Department of Roads to define the annual peak discharge. Figure 2 shows the location of the 142 stations. The symbols on the map identify the type of station and the number shown on the map corresponds to the number preceding the station name in table 1.

Table 1.—*Period of record of annual peaks at gaging stations*

[Solid bar: Peak stage and (or) discharge. Open bar: Peak stage only]

No.	Gaging station	Drainage area (square miles) Total	Contributing
	White River basin		
4432	White River tributary near Glen	7.97	7.97
4437	Soldiers Creek near Crawford	52.6	52.6
4440	White River at Crawford	313	313
4448	Chadron Creek near Chadron	14.9	14.9
	Ponca Creek basin		
4535	Ponca Creek at Anoka	410	410
	Niobrara River basin		
4563	Pebble Creek near Dunlap	23.5	23.5
4564	Cottonwood Creek near Dunlap	82.2	82.2
4577	Antelope Creek at Gordon	61.1	61.1
4578	Antelope Creek tributary near Gordon	26.6	26.6
4585	Bear Creek near Eli	360	78
4595	Snake River near Burge	620	100
4610	Minnechaduza Creek at Valentine	510	200
4625	Plum Creek near Meadville	581	330
4635	Long Pine Creek near Riverview	390	390
	Bazile Creek basin		
4665	Bazile Creek near Niobrara	440	440
	Omaha Creek basin		
6006	South Omaha Creek tributary near Walthill	2.64	2.64
6007	South Omaha Creek near Walthill	15.1	15.1
6008	South Omaha Creek tributary 2 near Walthill	1.51	1.51
6009	South Omaha Creek at Walthill	51.0	51.0
6010	Omaha Creek at Homer	170	170



[a] 1920 (stage only)

	Tekamah Creek basin		
6077	South Branch Tekamah Creek near Craig	2.54	2.54
6078	South Branch Tekamah tributary near Tekamah	4.08	4.08
6079	South Branch Tekamah Creek near Tekamah	9.73	9.73
6080	Tekamah Creek at Tekamah	23.0	23.0
	New York Creek basin		
6086	New York Creek near Spiker	1.75	1.75
6087	New York Creek tributary near Spiker	1.55	1.55
6088	New York Creek north of Spiker	6.50	6.50
6089	New York Creek east of Spiker	13.9	13.9
6090	New York Creek at Herman	25.4	25.4
	Platte River basin		
6840	Red Willow Creek near Bayard	162	162
6870	Blue Creek near Lewellen	267	80
6920	Birdwood Creek near Hershey	286	80
7671	South Fork Plum Creek tributary near Farnam	9.81	9.81
7673	Plum Creek tributary at Farnam	19.8	19.8
7674	North Plum Creek near Farnam	38.3	38.3
7674.1	Plum Creek near Farnam	79.8	79.8
7675	Plum Creek near Smithfield	229	229
7681	East Branch Buffalo Creek tributary near Buffalo	5.24	5.24
7682	East Branch Buffalo Creek near Buffalo	32.8	28.3
7683	East Branch Buffalo Creek tributary 2 near Buffalo	2.10	2.10
7684	West Branch Buffalo Creek near Buffalo	16.3	16.3
7685	Buffalo Creek near Darr	63	58.5
7690	Buffalo Creek near Overton	175	170
7691	Elm Creek tributary near Overton	.54	.54
7692	Elm Creek near Sumner	14.9	14.9
7693	Elm Creek tributary 2 near Overton	5.19	5.19
7695	Elm Creek near Overton	31	31
7707	Wood River near Lodi	12.9	12.9
7708	Wood River near Oconto	26.4	26.4
7709	Wood River at Oconto	44.8	44.8
7709.1	Wood River near Lomax	79.6	77.9
7710	Wood River near Riverdale	379	379
7730	Dry Creek at Cairo	22.2	22.2
7750	Middle Loup River near Seneca	1,140	60

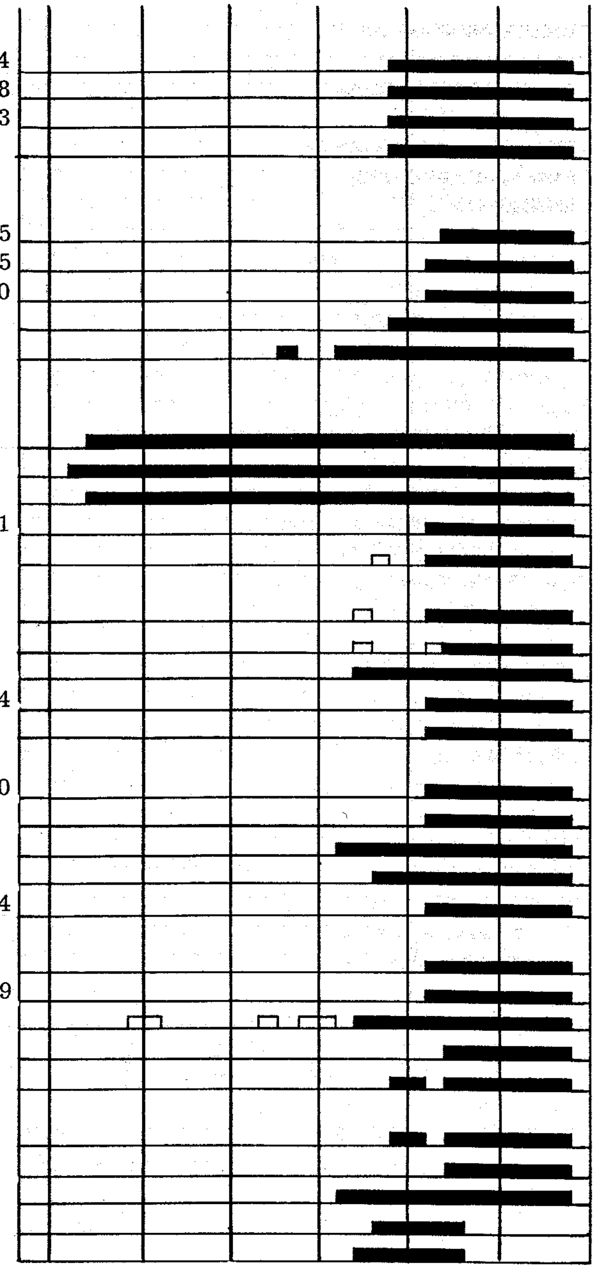
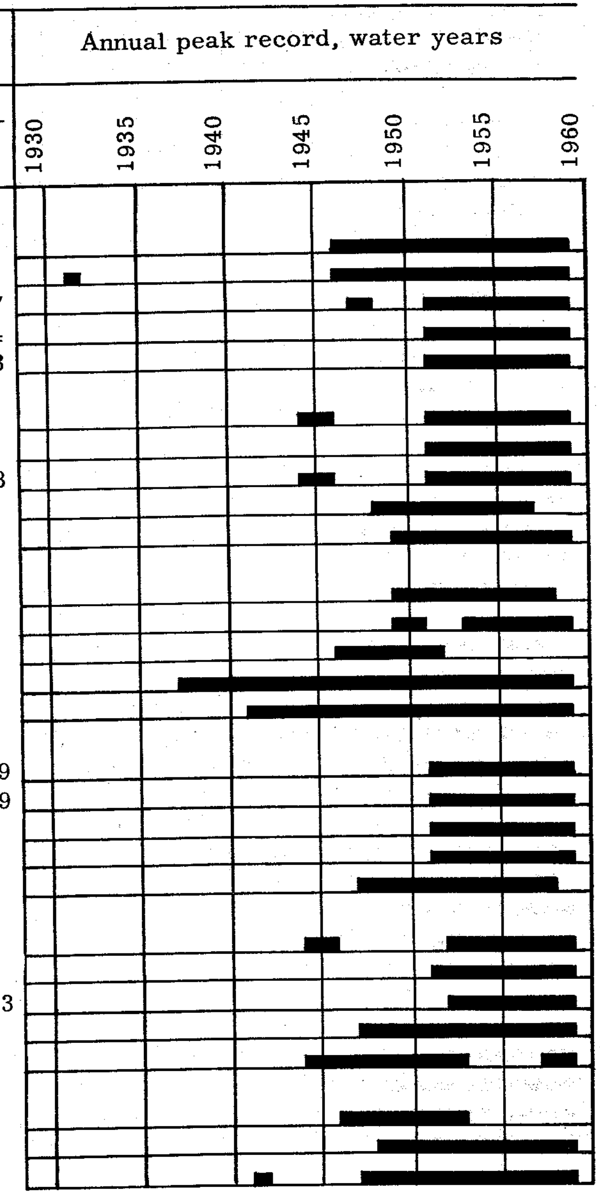
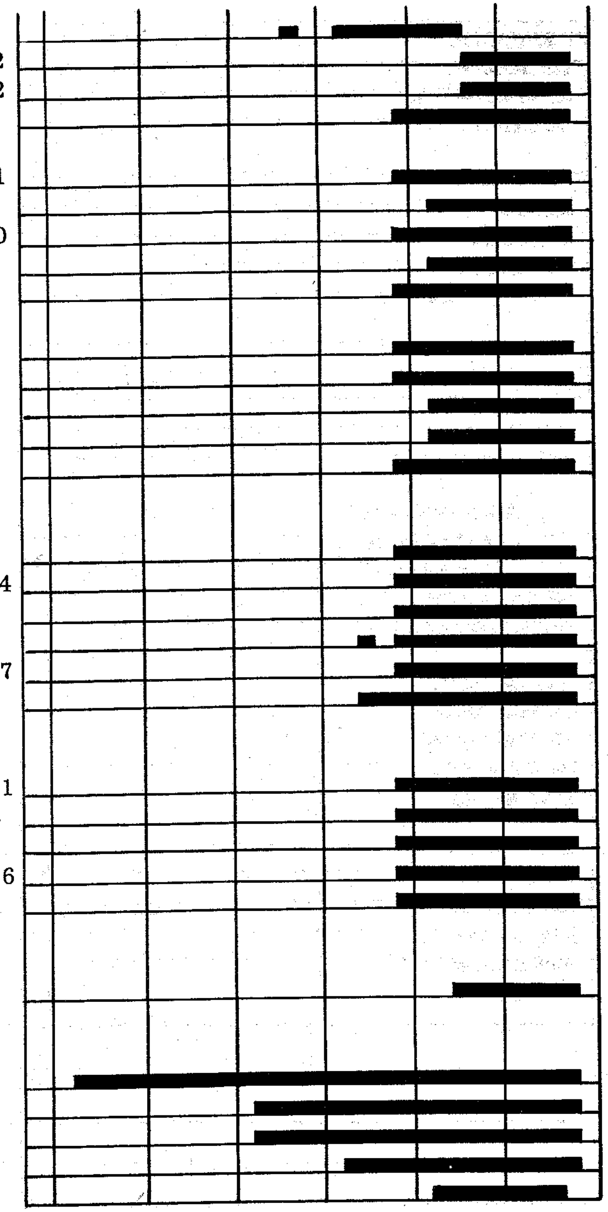


Table 1.—*Period of record of annual peaks at gaging stations*—Continued

No.	Gaging station	Drainage area (square miles) Total	Contributing
	Platte River basin—Continued		
7755	Middle Loup River at Dunning	1,760	80
7765	Dismal River at Dunning	1,780	50
7777	Lillian Creek near Broken Bow	4.77	4.77
7778	Lillian Creek tributary 2 near Walworth	2.04	2.04
7826	South Branch Mud Creek tributary near Broken Bow	.43	.43
7827	South Branch Mud Creek at Broken Bow	400	45.9
7828	North Branch Mud Creek at Broken Bow	15.5	10.8
7829	Mud Creek tributary near Broken Bow	5.98	5.98
7830	Mud Creek near Broken Bow	440	81.1
7843	Oak Creek near Loup City	41.9	41.9
7845	Oak Creek near Dannebrog	122	122
7847	Turkey Creek near Farwell	27.2	27.2
7855	North Loup River at Brewster	1,890	140
7860	North Loup River at Taylor	2,210	180
7875	Calamus River near Burwell	1,260	110
7891	Davis Creek tributary near North Loup	2.29	2.29
7892	Davis Creek tributary 2 near North Loup	6.79	6.79
7893	Davis Creek near North Loup	21.1	21.1
7894	Davis Creek southwest of North Loup	41.6	41.6
7895	Davis Creek near Cotesfield	94	94
7907	West Branch Spring Creek at Brayton	19.5	19.5
7908	West Branch Spring Creek near Wolbach	36.9	36.9
7909	Mary's Creek at Wolbach	7.63	7.63
7911	Spring Creek near Cushing	165	165
7915	Cedar River near Spalding	794	50
7935	Beaver Creek at Loretto	311	100
7950	Shell Creek at Newman Grove	122	122
7955	Shell Creek near Columbus	270	270



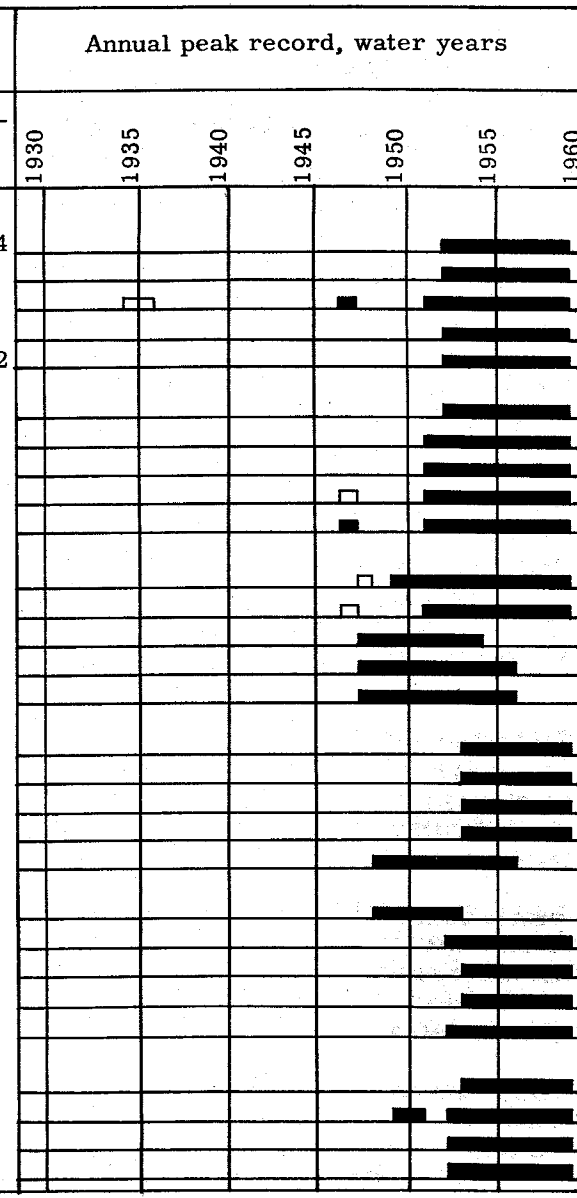
7980	South Fork Elkhorn River at Ewing	320	190
8015	Salt Creek subwatershed 12 at Roca	1.12	1.12
8025	Salt Creek subwatershed 34 near Roca	5.72	5.72
8030	Salt Creek at Roca	174	174
8035.7	Wahoo Creek tributary near Weston	.31	.31
8036	North Fork Wahoo Creek near Prague	15.2	15.2
8037	Dunlap Creek near Weston	8.90	8.90
8039	North Fork Wahoo Creek at Weston	43.7	43.7
8040	Wahoo Creek at Ithaca	272	272
8041	Silver Creek near Cedar Bluff	10.9	(b)
8042	Silver Creek near Colon	29.9	(b)
8043	Silver Creek tributary near Colon	14.3	(b)
8044	Silver Creek tributary at Colon	22.4	(b)
8045	Silver Creek at Ithaca	72	(b)
	Weeping Water Creek basin		
8064	Weeping Water Creek at Elmwood	21.4	21.4
8064.2	Stove Creek near Elmwood	4.94	4.94
8064.4	Stove Creek at Elmwood	10.0	10.0
8064.6	Weeping Water Creek at Weeping Water	75.5	75.5
8064.7	Weeping Water Creek tributary near Weeping Water	1.07	1.07
8065	Weeping Water Creek at Union	238	238
	Little Nemaha River basin		
8101	Hooper Creek tributary near Palmyra	7.81	7.81
8102	Hooper Creek near Palmyra	57.5	57.5
8103	Owl Creek near Syracuse	25.4	25.4
8104	Little Nemaha River tributary near Syracuse	.76	.76
8105	Little Nemaha River near Syracuse	218	218
	Nemaha River basin		
8155	Muddy Creek at Verdon	188	188
	Kansas River basin		
8230	North Fork Republican River at Colo.-Nebr. State line	320	130
8235	Buffalo Creek near Haigler	180	21
8240	Rock Creek at Parks	180	14
8360	Blackwood Creek near Culbertson	290	290
8390	Medicine Creek at Maywood	270	82



[b]Undetermined amount is noncontributing.

Table 1.—*Period of record of annual peaks at gaging stations*—**Continued**

No.	Gaging station	Drainage area (square miles) Total	Contributing
	Kansas River basin—**Continued**		
8392	Elkhorn Canyon near Maywood	6.74	6.74
8394	Elkhorn Canyon southwest of Maywood	13.2	13.2
8395	Brushy Creek near Maywood	130	72
8396	Frazier Creek near Maywood	11.3	11.3
8397	Frazier Creek tributary near Maywood	.72	.72
8398.5	Fox Creek north of Curtis	13.8	13.8
8399	Fox Creek above Cut Canyon near Curtis	31.8	31.8
8399.5	Cut Canyon near Curtis	25.6	25.6
8400	Fox Creek at Curtis	77	77
8405	Dry Creek near Curtis	20	20
8415	Mitchell Creek above Harry Strunk Lake	53	53
8440	Muddy Creek at Arapahoe	243	243
8500	Turkey Creek at Naponee	138	138
8502	Cottonwood Creek near Bloomington	15.6	15.6
8510	Center Creek at Franklin	146	57.4
8511	West Branch Thompson Creek at Hildreth	27.4	27.4
8512	West Branch Thompson Creek near Hildreth	56.6	56.6
8513	West Branch Thompson Creek tributary near Hildreth	13.9	13.9
8514	West Branch Thompson Creek near Upland	90.8	90.8
8515	Thompson Creek at Riverton	223	223
8520	Elm Creek at Amboy	39.2	39.2
8807.1	School Creek tributary near Harvard	13.1	13.1
8807.2	School Creek near Harvard	55.1	55.1
8807.3	School Creek tributary 2 near Harvard	14.0	14.0
8807.4	School Creek near Saronville	89.4	89.4
8836	South Fork Big Sandy Creek near Edgar	15.2	15.2
8837	South Fork Big Sandy Creek near Davenport	32.0	32.0
8838	South Fork Big Sandy Creek near Carleton	49.4	49.4
8839	South Fork Big Sandy Creek near Hebron	81.9	81.9



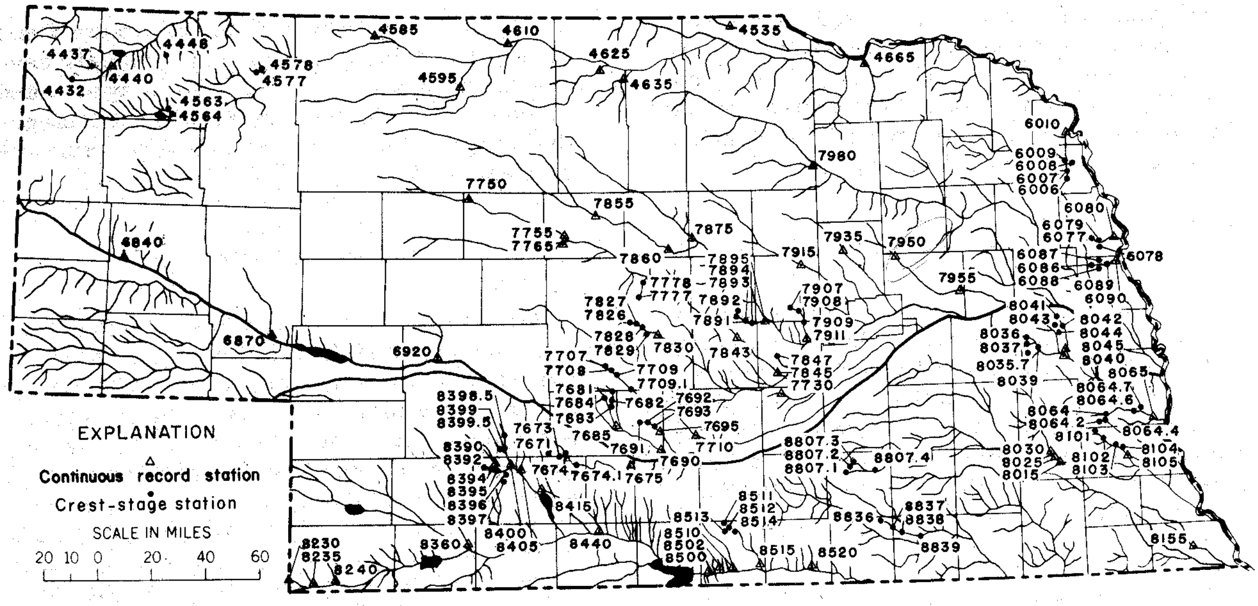


Figure 2. —Map of Nebraska showing location of gaging stations used in flood-frequency analysis.

FLOOD-FREQUENCY ANALYSIS

FLOOD FREQUENCY AT A GAGING STATION

VALUE

A regional frequency curve is considered to be superior to an individual station frequency curve; however, an analysis must be made at each gaging station before a regional study can be started.

The flood history at a gaging station is a record of what has happened at that particular site during the specified period of observation which is relatively short, statistically speaking. Such a record is only a chance sample of the flood potential representing the overall flood-frequency relation and as such may be a poor example for predicting what will happen in the future, even at the same site.

TYPES OF SERIES

There are two methods in general use for studying the frequency of floods: an annual flood series and a partial-duration series.

An annual flood is defined as the greatest momentary peak discharge in a water year (October 1 to September 30). In the annual flood array, the recurrence interval is the average interval in which a flood of a certain magnitude has occurred once as an annual maximum. An objection to the use of annual flood is that the second highest flood in a given high year may outrank many annual floods.

The partial-duration series is a list of all floods above a selected base. The base is generally selected as equal to the lowest annual flood so that at least one flood in each year is included. In the partial-duration series the recurrence interval is the average interval of time between floods of a given magnitude. An objection to the use of the partial-duration series is that the floods listed may not be fully independent events.

A definite relation exists between values in the two series as shown by Langbein (1949) and Chow (1950). The following table shows comparative values of recurrence intervals derived by the two methods:

Recurrence intervals in years

Annual flood series	*Partial-duration series*
1.16	0.5
1.58	1.0
2.00	1.45
2.54	2.0
2.52	5.0
10.5	10
20.5	20
50.5	50
100.5	100

The annual flood series is used in this report. Where a frequency curve derived from the partial-duration series is desired, an annual-flood curve can be converted to the partial-duration series curve by the relation expressed in the preceding table.

PLOTTING POSITION

The analysis of flood data starts with a listing of all the annual peaks at a gaging station. These are ranked according to magnitude starting with 1 as the highest. A time scale must be computed, to obtain a plotting position for the frequency scale. There are several methods, but the one used by the Survey and in this report is

$$T = \frac{n+1}{m}$$

where

T is the recurrence interval in years,
n is the number of years of record,
m is the order of the mganitude of the flood, the highest being 1.

In the study of historical floods, n is the number of years in which it is known that the flood was of the order assigned.

Annual floods are plotted on a special form devised by Powell (1943) on which the discharge is plotted on a linear scale as the ordinate and the recurrence interval on a scale graduated on the basis of the theory of extreme values as the abscissa.

HISTORICAL DATA

Historical floods can be used to extend the frequency curve of a station to cover a longer period. Historical data, however, are usually confined to stages or comparison of stages above a high base and it is important to define their order of magnitude with respect to a period of time. Historical information on small streams is more difficult to obtain than on larger streams because the duration of the flood is quite short and the number of people affected is very limited. Care must be exercised in assigning discharge values to historical stages because of possible channel changes.

Some information on historical floods was obtained, usually from local residents. Generally it is confined to the maximum flood during the memory of one or possibly several individuals. Some of the stages noted are beyond the limits of the defined stage-discharge relation, and a discharge could not be estimated.

FITTING FREQUENCY CURVES

After the flood discharges for each station have been plotted against their computed recurrence intervals, a curve is drawn on the basis of the plotted points. The relatively short length of most streamflow records and the probable inaccuracies of small samplings do not warrant analytical curve fitting. Therefore, a visual best fit smooth curve is used in this report to average the points. It is known that the maximum flood or floods of record may have a recurrence interval considerably greater than the period of record. Therefore, in drawing a best fit smooth-frequency curve, more weight is given to the lower floods than to the higher floods. Figure 3 shows a plot of the frequency of annual floods for Plum Creek near Smithfield, Nebr.

LIMITATIONS OF A SINGLE STATION ANALYSIS

Generally the 25-year or the 50-year flood is selected as the design flood. Table 1 shows that there are no gaging stations in Nebraska

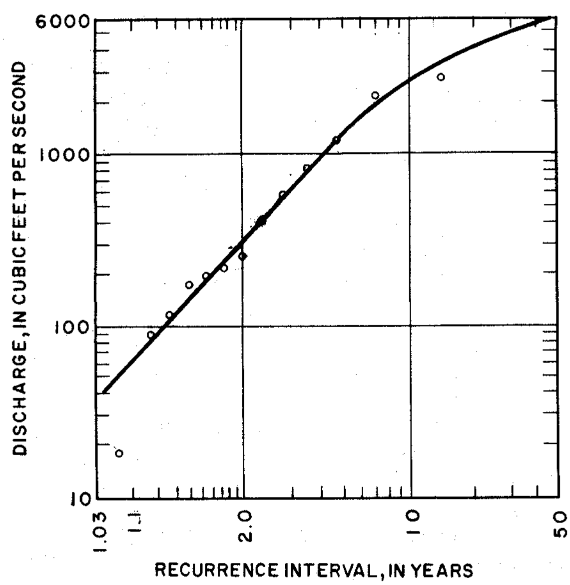


Figure 3. —Frequency of annual floods, Plum Creek near Smithfield, Nebr.

with less than a 300 square mile drainage area which have 50 years of record of annual peaks and that there are only 5 stations which have more than 25 years of record of annual peaks. Of the total 142 stations, 113 have only 10 years or less of record of annual peaks. To define a 25-year or 50-year flood would require extensive extrapolation from the trend of the plotting position of lesser floods. The error of the curve could be considerable at its outer extremity.

The random manner in which flood events are distributed with respect to time is another limitation to frequency graphs based on records at a single station.

The maximum departure to be expected between flood magnitudes or frequencies computed from relatively short records and their true (long-term) values increases with the magnitude of the flood and decreases with the length of record (Benson, 1960). The following table, based on Benson's study, shows the length of record required at a single site to define the frequency of floods of various magnitudes with 10 and 25 percent of the true value 19 out of 20 times.

Magnitude of flood, in recurrence intervals	*Length of record, in years*	
	10 percent	*25 percent*
2.33-year	40	12
10-year	90	18
25-year	105	31
50-year	110	39

Although the figures in the above table are based on a hypothetical study, they give an indication of the possible errors, from chance alone, in frequency graphs based on short-term records for a single station. A comparison of the lengths of stream records available in Nebraska on drainage areas of 300 square miles and less (table 1) with those indicated by Benson (1960) suggests that very few records in the State are long enough to define reliably the mean annual flood, and the floods of infrequent occurrence are less accurately defined. Analysis on a regional basis is used as a solution to the flood-frequency definition.

REGIONAL FLOOD-FREQUENCY ANALYSIS

A flood-frequency curve based on a number of stations has greater reliability than a curve from a single station. In order to combine the records for a number of stations, two requirements must be met. The first condition is that all the records must be reduced to a common time basis or base period, and the second is that the stations must have frequency graphs of the same general shape and slope, within limits of chance, so that they may be considered homogeneous.

BASE PERIOD

Table 1 shows graphically the length of usable records at the 142 gaging stations. Not all stations have records of the same length. If they are to be combined, records must be on the same time basis. The actual length of a short-period record of at least 5 years' duration can be extended by correlation with the long-term record of a nearby station. This correlation, however, is more sensitive for small streams than for larger streams and requires a long-term station in the immediate vicinity. Therefore, because there is such meager distribution of long-term stations within the State, the base period selected is 1947–59. Inasmuch as this base period is so short, it was also necessary to analyze records for 33 long-term stations having drainage areas greater than 300 square miles. This analysis was made for the period 1929–59 in order to establish the relation of the short base period to a 31-year period.

The actual record at each station either included or was extended to the 13-year base period, and for the 33 long-term stations mentioned above, to the 31-year period by computing a discharge figure for each year of no record. These computed discharges, which are based on correlation with records for long-term stations, are used only to assign the more nearly correct order numbers to annual peaks of record.

DEFINITION OF MEAN ANNUAL FLOOD

According to the theory of extreme values as applied to floods by Gumbel (1945), the arithmetic mean of the annual peak discharges in an infinitely long series is equal to the discharge corresponding to the 2.33-year recurrence interval. This definition is generally accepted, and the 2.33-year flood determined graphically is used as the mean annual flood for this report. Annual-flood data for each of the individual gaging stations were adjusted to the 13-year base period (1947–59).

HOMOGENEITY OF RECORDS

The test for homogeneity of records involves determining whether differences in slopes of individual frequency curves are greater than might occur by chance in random sampling. This statistical test has a 95-percent confidence level, that is, one station in 20 may plot outside the limits of the test graph. The slope of each individual station frequency curve is expressed by the ratio of the 10-year flood to the mean annual flood. The average ratio derived from the group was multiplied by the mean annual flood for each individual station and the corresponding recurrence interval was determined from the station frequency graph. The recurrence interval thus obtained was then plotted against the effective length of record in years on the specially designed test graph. The effective length of record is the number of annual floods of record plus one-half the number of estimated annual floods used to complete the base period.

The test applied to the 142 gaging stations used in this report indicates two homogeneous flood regions in Nebraska which are designated as regions A and B. The regional boundaries are shown in figure 4. Region B is the Sand Hills, and region A consists of the remaining part of the State. There are 132 stations in region A and 10 stations in region B.

COMPOSITE FREQUENCY CURVES

In order to compare flood records at different gaging stations and combine them to define composite flood relations, it is necessary to convert the floods to a dimensionless basis. This was done by computing the ratio of floods of selected recurrence intervals to the mean annual flood for each gaging station in a homogeneous region. The median ratio of each selected recurrence interval was then plotted against the corresponding recurrence interval to give the composite frequency curve for each homogeneous region (fig. 5).

RELATIONS OF MEAN ANNUAL FLOOD

The composite frequency curves as derived in the preceding section define dimensionless ratios of the mean annual flood to floods of other recurrence intervals. In order to define the flood-frequency curve in terms of discharge for a specific site, the magnitude of the mean annual flood is required. The magnitude of the mean annual flood is obtained by relating it to measurable characteristics of the drainage basin.

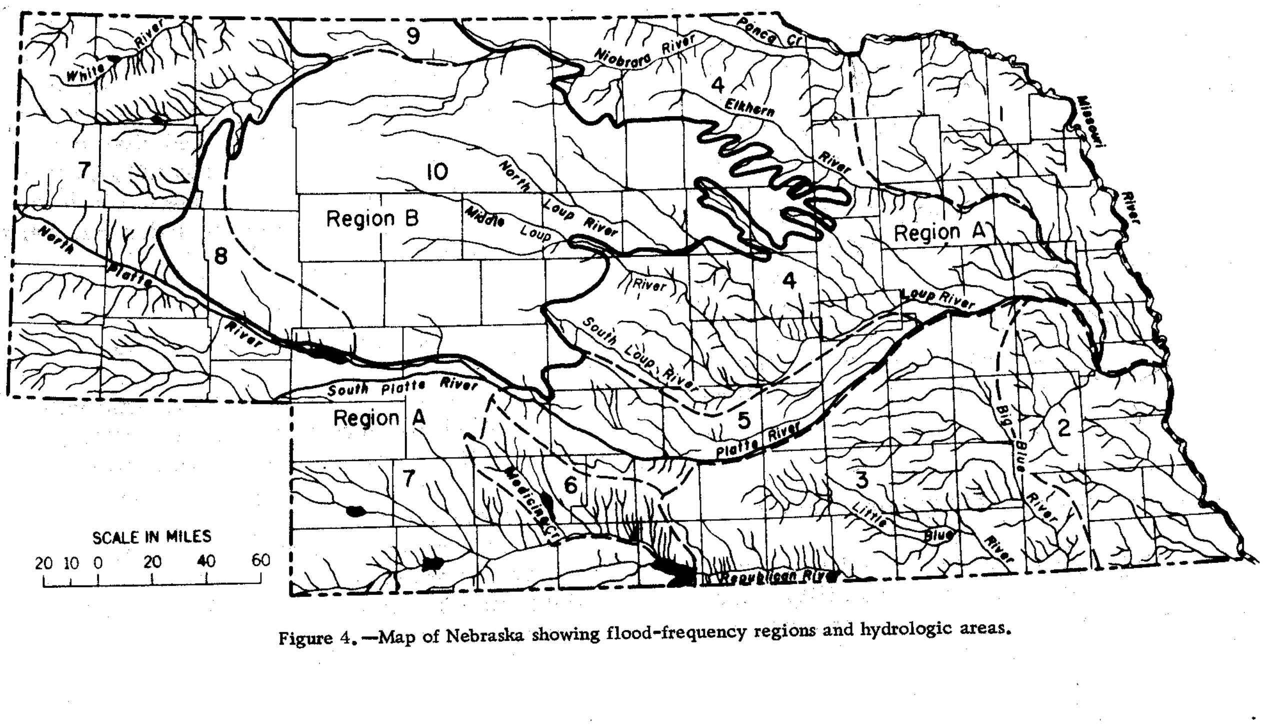


Figure 4.—Map of Nebraska showing flood-frequency regions and hydrologic areas.

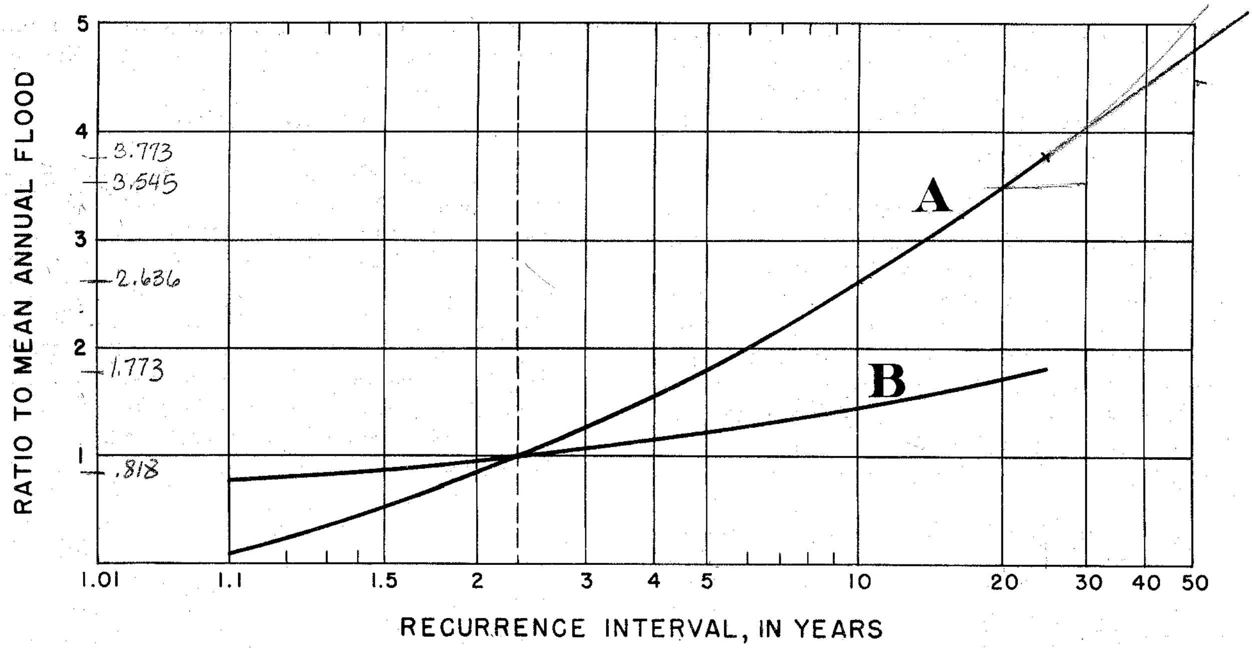


Figure 5.—Composite frequency curves of annual floods, regions A and B, period 1947–59.

The physiographic factors which may influence the mean annual flood at a given point are size of the drainage basin, shape of the basin, alinement of the basin with the prevailing direction of storm travel, channel storage, artificial or natural storage in lakes or ponds, slope of stream, land slope, stream density, stream pattern, altitude, depth and porosity of soil mantle, vegetal cover and land use. Some of these factors are difficult to evaluate and therefore cannot be used in a correlation.

The mean flow of a stream is a hydrologic measure that integrates all factors of runoff and thus includes an indication of flood potential. Because the majority of the station records used in this report are from crest-stage gages at which total runoff is not measured, the mean flow had to be determined from streams which have larger drainage areas and which are not always strategically located.

The mean annual flood was correlated graphically with contributing drainage area, mean flow, stream slope, and shape of basin factor. The drainage area size, the mean flow, and stream slope are all significant factors, drainage area and mean flow being the most significant. The correlations, however, do not give consistent results and inasmuch as mean flow was inadequately defined, the contributing drainage area alone was used to define a relation with the mean annual flood. Along with variations in mean flow, other factors or combination of factors that influence floods are not reflected in the size of the basin, but their effect is related in areas having somewhat similar physical features. Accordingly, the State was subdivided into 10 hydrologic areas shown in figure 4. Except for the boundaries of the regions A and B which are also boundaries of hydrologic areas, the boundaries of the hydrologic areas follow the drainage divides or major streams.

Records for the 33 long-term stations mentioned under "Base Period" above were used in order to define mean annual flood relations with respect to time. The graphical definition of the mean annual flood for the 31-year (1929–59) base period was compared to the mean annual flood defined by the 13-year (1947–59) base period at each of the 33 individual stations which are distributed around and within the State. This study revealed that the average correction factor required to adjust the mean annual flood from the 13-year period to the 31-year period in the 10 hydrologic areas is as follows:

Area	*Correction factor*
1 and 2	0.816
3 and 4	.925
5, 8, 9, and 10	1.00
6 and 7	1.08

The above adjustments are reasonably well established in all areas except in area 7 where there is considerable spread in results for individual stations used to define the average correction.

The mean annual flood for each station determined from the 13-year period was corrected by the average correction factor for the hydrologic area in which the station was located. For each of the 10 hydrologic areas, the corrected mean annual flood for each station in that area was plotted against the contributing drainage area for the station. Curves were drawn to average all the data in each area. The variation of mean annual flood with contributing drainage area for each of the 10 hydrologic areas is shown in figure 6.

HYDROLOGIC AREAS

Area 1, as shown in figure 4, is the northeast corner of the State. It includes all the smaller streams downstream from the Niobrara River and upstream from the Platte River which are direct tributaries of the Missouri River. It also includes the left bank tributaries of the Elkhorn River which are downstream from the Sand Hill area. The area is generally quite hilly. The variation of the mean annual flood with drainage area is defined by 15 stations.

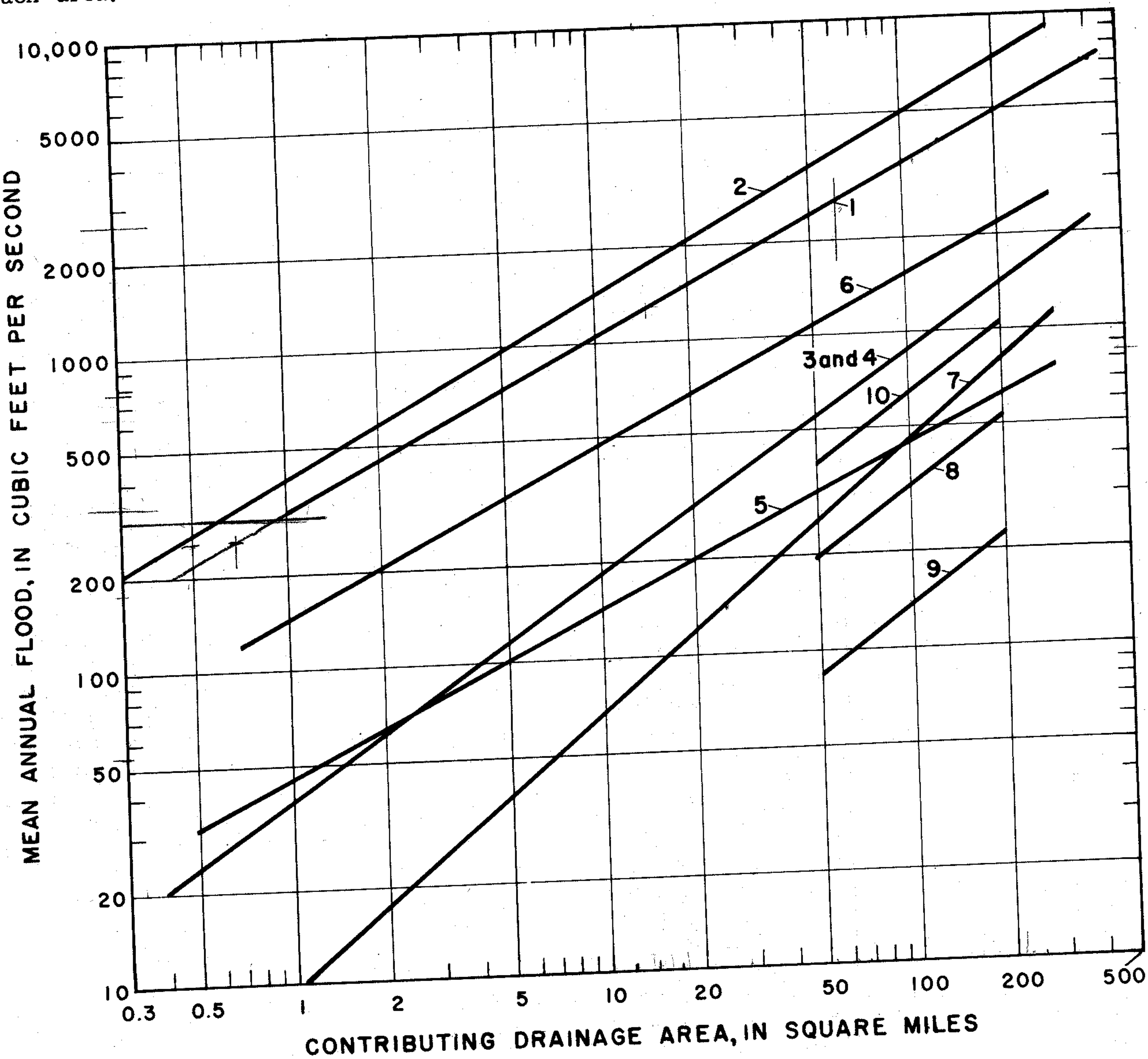


Figure 6.—Variation of mean annual flood with contributing drainage area in hydrologic areas 1–10.

Area 2 is the southeast corner of the State. It includes Salt Creek, a tributary of the Platte River, and all direct tributaries of the Missouri River in the State downstream from the Platte River. This area is also quite hilly except for a flat area in Saunders County which probably is the remains of an old Platte River channel. The five Silver Creek stations included in this report are in this flat area and their drainage areas include many depressions which trap water and prevent it from reaching the stream. Available topographic maps for this flat area do not distinguish between the contributing and the noncontributing area. Twenty-five stations are in area 2, but because the contributing drainage of the five Silver Creek stations is not defined, the curve of variation of mean annual flood with drainage area is drawn on the basis of the data from the 20 remaining stations. The mean annual floods are higher than those in area 1 because of the greater mean annual rainfall and resulting greater mean flow.

Area 3 (fig. 4) consists of the south-central plains of the State. It contains the Big Blue River, the Little Blue River, and the tributaries of the Republican River downstream from Harlan County Dam. The headwaters of these streams drain gentle sloping land, and there are some depressions which trap runoff and prevent it from reaching the streams. Seventeen stations are used to define the variation of the mean annual flood with drainage area.

Area 4 (fig. 4) includes Ponca Creek, the tributaries of the lower part of the Niobrara River, the upper part of the Elkhorn River and all its right-bank tributaries, the Loup River basin downstream from the Sand Hills, and the left-bank tributaries of the Platte River between the Loup River and the Elkhorn River. This area has a wide variety of topography and soils. Flood flow at some of the stations is materially affected by the proximity of the porous Sand Hills. Generally, it is possible to determine the contributing drainage area if good topographic maps are available. Good topographic maps have not been made for this area; therefore, some of the drainage areas are listed as approximate. Twenty-eight stations are used to define the variation of the mean annual flood with the contributing drainage area. The resulting curve is so similar to that for area 3 that one curve is shown on figure 6 as representative of both hydrologic areas.

Area 5 (fig. 4) includes the small tributaries of the Platte River in the central part of the State. The area contains some low rolling hills at the headwaters of the streams and at the perimeter of the area but toward the interior the land and stream slopes become less. As the drainage area increases, channel storage becomes a factor in reduction of the mean annual flood. Twenty-one stations are used to define the variation of the mean annual flood with drainage area.

Area 6 (fig. 4) includes the Medicine Creek basin and all left-bank tributaries of the Republican River between Medicine Creek and Harlan County Dam. This area is very hilly and contributes to surface runoff, except for the upper reaches of the Medicine Creek basin where part of the Sand Hills is located. Thirteen stations are used for defining the variation of the mean annual flood with the drainage area.

Area 7 (fig. 4) is the western part of the State that includes drainage basins of the Republican, South Platte, North Platte, Niobrara, and White Rivers. This area has a wide variety of topography and soils. Some parts of the Republican River basin have depressions and sandy areas which do not contribute to surface runoff. Thirteen stations are used to define the relation of the mean annual flood to the contributing drainage area. The definition in area 7 is considered to be the poorest in the State.

Area 8 is the southwestern part of the Sand Hills as shown in figure 4; it is defined on the basis of only one station record. The station frequency curve indicates that mean annual floods are considerably lower than those defined in area 10. The relation of the mean annual flood to contributing drainage area is defined by the one station and the slope of the relationship curve defined in area 10.

Area 9 (fig. 4) is the part of the Sand Hills north of the Niobrara River. As in area 8, only one station record is available. The station frequency curve indicates that mean annual floods are considerably lower than those in area 10. The relationship curve, as shown in figure 6, is based on the one station record and the slope of the relationship curve defined for area 10.

Area 10 (fig. 4) contains the greater part of the Sand Hills which generally drain to the south and east. Only the area immediately adjacent to the streams contributes to surface runoff; the high base flow comes from ground water. The contributing drainage areas of the eight stations in this area are not very well defined and are listed as approximate. The range in size of the contributing drainage area is from 50 to 140 square miles.

The definition of the mean annual flood with respect to contributing drainage area covers the range of drainage area from 1 to 300 square miles in hydrologic areas 1–7. The range of drainage area defined in areas 8–10 is from 50 to 200 square miles.

APPLICATION OF REGIONAL FLOOD-FREQUENCY DATA

TRIBUTARY AREAS OF NATURAL RUNOFF

This section gives step-by-step procedures for determining the magnitudes of floods in Nebraska having any recurrence interval up to 25 years at any site not subject to man-made regulation or control that has a contributing drainage area between 1 and 300 square miles in region A and between 50 and 200 square miles in region B (fig. 4).

1. Determine the total and contributing drainage areas at the site. The contributing drainage area is that part of the total basin area that contributes directly to surface runoff.

2. From figure 4, obtain the number of the hydrologic area and the flood region in which the site is located.

3. With the contributing drainage area (step 1) and the number of the hydrologic area (step 2), determine the mean annual flood for the site from figure 6.

4. With the flood region (step 3) determine the ratio to the mean annual flood for the flood of the selected frequency of recurrence from figure 5.

5. Multiply the ratio of the selected flood to the mean annual flood (step 4) by the mean annual flood determined in step 3 to obtain the flood magnitude at the site. If a complete frequency graph is desired, repeat steps 4 and 5 for a number of recurrence intervals.

It must be emphasized that the curves cannot be extrapolated with confidence beyond the limits of the base data from which the curves were derived.

STAGE OF FLOOD DISCHARGE

This report deals specifically with the frequency of flood discharges. Flood stage corresponding to these discharges may also be of primary concern in the design of certain structures and in other related studies. For rock-lined or firm-bedded streams at sites not subject to variable backwater from downstream inflow or structures, a stage-discharge relation provides a ready solution to the problem. For shifting-channel streams of Nebraska and where variable backwater may exist, the stage corresponding to the selected discharge may be approximated only after extensive research. If the stage is to be investigated, the engineer will find the site in question to be in one of two categories:

1. Site at or near an established gaging station. Gaging stations have been maintained at several hundred sites in Nebraska. Locations of those established prior to September 30, 1950, are described in reports of the Geological Survey (Water-Supply Papers 1309 and 1310). Stations established since 1950 are described in the annual series of water-supply papers entitled "Surface Water Supply of the United States." A reasonable stage-discharge relation has been established at each of the small-area stations used for this report, and may be examined in the Lincoln office of the Geological Survey. For sites at or near gaging stations, it is usually possible to obtain stage data that are adequate for most purposes.

2. Site not near an established gaging station. The stage corresponding to a discharge of selected recurrence interval must generally be obtained through the medium of a stage-discharge relation. The extent of the investigation required to establish such a relation will depend upon the accuracy requirements. The following methods of deriving a stage-discharge relation are noted in decreasing order of reliability. (a) If the need for data can be anticipated far enough in advance, discharge measurements may be obtained to define the relation up to the maximum discharge observed in the period. The

relation may be extended by the application of measured channel characteristics to appropriate hydraulic formulas. Shifting-channel characteristics may be investigated by studies of bed material and some long-term changes may be obtained from local residents. (b) If the need for data is immediate, the discharge for a past flood may be computed by hydraulic formulas if adequate floodmarks can be recovered and one point on the stage-discharge relation curve thereby established. A direct measurement of discharge at the time of the visit will provide one other point. (c) A method has been used to develop ratings for stable channels from the product of the stream slope at zero flow or low flow and characteristics of conveyance at a typical cross section. This method is unsuited to streams with unstable channel beds.

MAXIMUM KNOWN FLOODS

The design of major hydraulic structures whose failure may cause loss of life should consider the maximum probable flood rather than one that may be expected to occur in a defined period of years. A prerequisite to such an analysis is the record of maximum known floods.

Maximum known stages and discharges at the 142 gaging stations used in the flood-frequency analyses are shown in table 2. The stations are listed in downstream order and the number preceding the station name corresponds with the numbers shown in table 1 and figure 2. The flood region and hydrologic area in which the station is located is shown as well as the total and contributing drainage area. The contributing drainage area is used to compute the peak discharge in cubic feet per second per square mile. The period of known floods is that for which the stage or discharge is known to be the greatest. The stage is given for each maximum discharge except for stations 7730 and 7829. The discharge at these two stations had been determined from an indirect measurement prior to the establishment of the gage and there is no datum tie between the survey and the gage. Where the maximum stage and the maximum discharge are not concurrent, a change in the stage-discharge relation is indicated, and no discharge figure is shown for the maximum stage. Some periods of known floods for the maximum stage are extended on the basis of recovered floodmarks beyond the period of known floods for the maximum defined discharge. For such periods, a leader line has been placed in the discharge column to indicate that the discharge for this known stage could not be defined within allowable limits of accuracy. A leader line in other columns is also used to indicate that the information could not be determined.

Twenty-five unusual peak discharges have been collected at miscellaneous sites or at short-term gaging stations which have 300 square miles or less contributing drainage area. These data are shown in table 3. The sites are listed in downstream order. Gaging stations having records of insufficient length to be included in the flood-frequency analysis have been operated or are being operated at numbered sites. Unnumbered sites are miscellaneous sites where only one observation has been made.

As shown in figure 5, there is a great difference in the composite frequency curve for region A and for region B, and the curves of figure 6 show that the mean annual flood for a given drainage area can vary considerably between hydrologic areas. A separate illustration was developed, therefore, for each of the 10 hydrologic areas on which the 10- and 25-year recurrence interval floods are shown as a curve to compare with the maximum discharge at the stations and miscellaneous sites in that hydrologic area. The maximum discharge at the 142 stations used in this frequency analysis are shown as open circles, and the maximum discharge at the miscellaneous sites and short-term gaging stations which are listed in table 3 are shown as closed circles. The gaging stations are identified by the last four or five digits of the index number, in order to correspond with those shown in tables 2 and 3.

The relation of the maximum discharge to the 10- and 25-year floods in the 10 hydrologic regions are shown in figures 7–11.

Table 2.—*Maximum stages and discharges at gaging stations*

Number	Gaging station	Flood region and hydro-logic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge				Station mean annual flood ($Q_{2.33}$ in cfs)	Ratio of maxi-mum to $Q_{2.33}$
			Total	Contrib-uting		Date	Gage height (feet)	Discharge			
								Cfs	Cfs per square mile		
	White River basin										
6A-4432	White River tributary near Glen	A7	7.97	7.97	1953–59	Sept. 20, 1955	13.30	300	37.6	32	9.4
4437	Soldiers Creek near Crawford	A7	52.6	52.6	1955–59	July 10, 1958	21.90	3,970	75.5	691	5.7
4440	White River at Crawford	A7	313	313	1931–44,	Mar. 15, 1948	6.88	[a]2,000	6.4	961	2.1
					1948–59	July 10, 1958	7.7	------	------	------	------
4448	Chadron Creek near Chadron	A7	14.9	14.9	1953–59	Aug. 29, 1954	13.72	1,610	108	238	6.8
	Ponca Creek basin										
4535	Ponca Creek at Anoka	A4	410	410	1949–59	Apr. 2, 1950	15.0	6,770	16.5	1,850	3.7
	Niobrara River basin										
4563	Pebble Creek near Dunlap	A7	23.5	23.5	1953–59	July 28, 1953	12.88	2,740	117	562	4.9
4564	Cottonwood Creek near Dunlap	A7	82.2	82.2	1948, 1951–59	July 28, 1951	20.10	28,100	342	1,296	21.7
4577	Antelope Creek at Gordon	A7	61.1	61.1	1953–59	May 24, 1958	17.86	444	7.3	76	5.8
4578	Antelope Creek tributary near Gordon.	A7	26.6	26.6	1953–59	June 17, 1955	16.69	1,900	71.4	63	30.2
4585	Bear Creek near Eli	B9	360	78	1948–53,	May 20, 1951	[b]5.07	145	1.9	115	1.3
					1950–53	Mar. 14, 1953	[b]5.20	------	------	------	------
4595	Snake River near Burge	B10	620	100	1948–59	Feb. 2, 1951	4.04	------	------	------	------
						May 26, 1955	3.16	577	5.8	470	1.2
4610	Minnechaduza Creek at Valentine	A4	510	200	1948–59	Mar. 30, 1952	6.58	894	4.5	185	4.8
4625	Plum Creek near Meadville	A4	581	330	1948–59	May 25, 1952	[c]4.46	[a]820	2.5	536	1.5
						June 19, 1953	[d]9.72	------	------	------	------
4635	Long Pine Creek near Riverview	A4	390	390	1949–53, 1955–59	Aug. 20, 1951	10.24	5,410	13.9	1,200	4.5
	Bazile Creek basin										
4665	Bazile Creek near Niobrara	A1	440	440	1951–59	June 16, 1957	19.96	68,600	156	9,790	7.0

	Omaha Creek basin										
6B-6006	South Omaha Creek tributary near Walthill.	A1	2.64	2.64	1950–59	June 16, 1957	14.57	1,410	534	343	4.1
6007	South Omaha Creek near Walthill	A1	15.1	15.1	1950–59	June 21, 1954	18.71	10,100	669	1,220	8.3
6008	South Omaha Creek tributary 2 near Walthill.	A1	1.51	1.51	1950–59	June 20, 1954	12.90	2,150	1,424	424	5.1
6009	South Omaha Creek at Walthill	A1	51.0	51.0	1951–59	June 13, 1957	24.92	14,200	278	1,470	9.7
6010	Omaha Creek at Homer	A1	170	170	1920–59	June 4, 1940	a 32.5	-------	-------	------	-----
					1946–59	July 2, 1958	23.62	14,400	84.7	4,080	3.5
	Tekamah Creek basin										
6077	South Branch Tekamah Creek near Craig.	A1	2.54	2.54	1950–59	July 15, 1950	21.3	a 2,580	1,020	661	3.9
6078	South Branch Tekamah Creek tributary near Tekamah.	A1	4.08	4.08	1950–59	...do	19.3	a 1,800	441	694	2.6
6079	South Branch Tekamah Creek near Tekamah.	A1	9.73	9.73	1950–59	Apr. 21, 1954	20.17	3,130	322	1,060	3.0
6080	Tekamah Creek at Tekamah	A1	23.0	23.0	1950–59	July 15, 1950	14.26	4,400	191	2,190	2.0
						Aug. 13, 1958	15.10	------	------	------	-----
	New York Creek basin										
6086	New York Creek near Spiker	A1	1.75	1.75	1952–59	June 15, 1957	16.19	1,380	789	359	3.8
6087	New York Creek tributary near Spiker.	A1	1.55	1.55	1951–59	June 21, 1957	17.80	1,580	1,020	392	4.0
6088	New York Creek north of Spiker	A1	6.50	6.50	1951–59	...do	23.40	3,160	486	1,040	3.0
6089	New York Creek east of Spiker	A1	13.9	13.9	1950–59	July 2, 1951	24.14	6,020	433	1,320	4.6
6090	New York Creek at Herman	A1	25.4	25.4	1944, 1946–59,	June 11, 1944	e 20.8	-------	------	------	-----
					1944, 1946–59	July 15, 1950	e 19.5	5,500	217	1,760	3.1
	Platte River basin										
6840	Red Willow Creek near Bayard	A7	162	162	1932–59	May 10, 1942	7.8	-------	------	------	------
						July 3, 1956	7.33	2,320	14.3	1,260	1.8
6870	Blue Creek near Lewellen	B8	267	80	1931–59	May 20, 1938	f 4.46	g 723	9.0	278	2.6
						Dec. 21, 1945	f 4.93	-------	------	------	------
6920	Birdwood Creek near Hershey	B10	286	80	1932–59	Dec. 15, 1940	5.12	-------	------	------	------
						Apr. 1, 1949	4.35	1,770	22.1	470	3.8
7671	South Fork Plum Creek tributary near Farnam.	A5	9.81	9.81	1951–59	June 8, 1951	13.88	1,170	119	440	2.7
7673	Plum Creek tributary at Farnam	A5	19.8	19.8	1925–59	June 22, 1948	a,h 18.8	-------	------	------	------
					1951–59	June 8, 1951	13.36	2,070	105	150	13.8

See footnotes at end of table.

Table 2.—*Maximum stages and discharges at gaging stations*—**Continued**

Number	Gaging station	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge				Station mean annual flood ($Q_{2.33}$ in cfs)	Ratio of maximum to $Q_{2.33}$
			Total	Contributing		Date	Gage height (feet)	Discharge			
								Cfs	Cfs per square mile		
	Platte River basin—**Continued**										
6B-7674	North Plum Creek near Farnam	A5	38.3	38.3	1947, 1951–59	June 22, 1947	[e]17.8	------	------	------	------
					1951–59	June 8, 1951	[e]14.3	385	10.1	200	1.9
7674.1	Plum Creek near Farnam	A5	79.8	79.8	1947, 1951–59	June 22, 1947	22.6	------	------	------	------
					1952–59	Apr. 22, 1957	12.20	170	2.1	140	1.2
7675	Plum Creek near Smithfield	A5	229	229	1947–59	June 23, 1947	23.41	2,800	12.2	410	6.8
7681	East Branch Buffalo Creek tributary near Buffalo.	A5	5.24	5.24	1951–59	July 19, 1958	13.31	208	39.7	60	3.5
7682	East Branch Buffalo Creek near Buffalo.	A5	32.8	28.3	------	------	[a,h]19.4	------	------	------	------
					1951–59	July 19, 1958	18.26	1,570	55.5	170	9.2
7683	East Branch Buffalo Creek tributary 2 near Buffalo.	A5	2.10	2.10	1951–59	June 12, 1958	12.52	172	81.9	40	4.3
7684	West Branch Buffalo Creek near Buffalo.	A5	16.3	16.3	1951–59	July 19, 1958	15.81	475	29.1	85	5.6
7685	Buffalo Creek near Darr	A5	63	58.5	1947–59	June 22, 1947	[e]18.4	9,000	154	260	34.6
7690	Buffalo Creek near Overton	A5	175	170	1949–58	July 12, 1958	10.47	383	2.3	225	1.7
7691	Elm Creek tributary near Overton	A5	.54	.54	1951–59	July 10, 1958	13.59	142	263	54	2.6
7692	Elm Creek near Sumner	A5	14.9	14.9	1951–59	---do-------	14.41	271	18.2	100	2.7
7693	Elm Creek tributary 2 near Overton.	A5	5.19	5.19	1951–59	---do-------	13.03	276	53.2	203	1.4
7695	Elm Creek near Overton	A5	31	31	1935–58	1935	[h]20.22	------	------	------	------
					1947–58	June 22, 1947	19.65	8,000	258	380	21.1
7707	Wood River near Lodi	A5	12.9	12.9	1952–59	June 16, 1955	11.63	142	11.0	90	1.6
7708	Wood River near Oconto	A5	26.4	26.4	1950,	June 17, 1954	14.47	790	29.9	600	1.3
					1952–59	------------	------	------	------	------	------
7709	Wood River at Oconto	A5	44.8	44.8	1950,	July 19, 1958	18.58	2,390	53.3	450	5.3
					1952–59	------------	------	------	------	------	------
7709.1	Wood River near Lomax	A5	79.6	77.9	1952–59	July 19, 1958	19.67	1,470	18.9	320	4.6

7710	Wood River near Riverdale	A5	379	379	1946–59	June 22, 1947	19.75	20,000	52.8	710	28.2
7730	Dry Creek at Cairo	A5	22.2	22.2	1949–53	June 6, 1949	------	1,100	46.6	570	1.9
					1950–53	May 27, 1953	7.64	586	------	------	------
7750	Middle Loup River near Seneca	B10	1,140	60	1948–53	Jan. 7, 1949	2.61	------	------	------	------
						Aug. 8, 1950	2.09	457	7.6	372	1.2
7755	Middle Loup River at Dunning	B10	1,760	80	1946–59	Mar. 31, 1949	7.02	------	------	------	------
						Sept. 13, 1958	3.90	830	10.4	670	1.2
7765	Dismal River at Dunning	B10	1,780	50	1946–59	Jan. 19, 1947	5.21	------	------	------	------
					1932,	May 26, 1952	3.18	996	19.9	564	1.8
					1946–59	------------		------	------	------	------
7777	Lillian Creek near Broken Bow	A4	4.77	4.77	1947–59	June 22, 1947	[e]12.2	930	195	74	12.6
7778	Lillian Creek tributary 2 near Walworth.	A4	2.04	2.04	1951–59	Aug. 12, 1951	[e]12.4	585	287	37	15.8
7826	South Branch Mud Creek tributary near Broken Bow.	A4	.43	.43	1951–59	July 18, 1958	12.43	184	428	74	2.5
7827	South Branch Mud Creek at Broken Bow.	A4	400	45.9	1948–59	June 17, 1956	16.41	1,790	39.0	74	24.2
7828	North Branch Mud Creek at Broken Bow.	A4	15.5	10.8	1951–59	---do---	16.16	1,550	144	194	8.0
7829	Mud Creek tributary near Broken Bow.	A4	5.98	5.98	1945, 1951–59	May 27, 1945	------	1,500	251	74	20.3
					1951–59	July 21, 1951	[e]14.80	870	------	------	------
7830	Mud Creek near Broken Bow	A4	440	81.1	1949–56	June 17, 1956	9.48	600	7.4	416	1.4
7843	Oak Creek near Loup City	A4	41.9	41.9	1950–59	July 3, 1951	[e]15.50	1,420	33.9	601	2.4
7845	Oak Creek near Dannebrog	A4	122	122	-------	------------	[e]19.0	------	------	------	------
					1950–57	June 17, 1954	17.23	1,880	15.4	1,210	1.6
7847	Turkey Creek near Farwell	A4	27.2	27.2	1950, 1953–59	July 9, 1950	[e]17.50	1,600	58.8	1,180	1.4
						------------	------	------	------	------	------
7855	North Loup River at Brewster	B10	1,890	140	1946–51	Feb. 25, 26, 1950	4.20	------	------	------	------
						June 14, 1951	[b]3.40	[a]1,600	11.4	840	1.9
7860	North Loup River at Taylor	B10	2,210	180	1937–59	---do---	6.50	[g]2,830	15.7	1,400	2.0
						Feb. 25, 1957	[e]9.5	------	------	------	------
7875	Calamus River near Burwell	B10	1,260	110	1941–59	Mar. 19, 1950	5.19	------	------	------	------
						May 16, 1951	3.76	1,060	9.6	558	1.9
7891	Davis Creek tributary near North Loup.	A4	2.29	2.29	1951–59	July 3, 1951	17.74	[a]906	396	324	2.8
7892	Davis Creek tributary 2 near North Loup.	A4	6.79	6.79	1951–59	July 14, 1957	16.82	722	106	194	3.7
7893	Davis Creek near North Loup	A4	21.1	21.1	1951–59	---do---	15.68	1,820	86.3	695	2.7
7894	Davis Creek southwest of North Loup.	A4	41.6	41.6	-------	------------	[e]21.5	------	------	------	------
					1951–59	June 16, 1957	19.35	2,220	53.4	1,040	2.1

See footnotes at end of table.

Table 2.—*Maximum stages and discharges at gaging stations*—Continued

Number	Gaging station	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge				Station mean annual flood ($Q_{2.33}$ in cfs)	Ratio of maximum to $Q_{2.33}$
			Total	Contributing		Date	Gage height (feet)	Discharge			
								Cfs	Cfs per square mile		
	Kansas River basin—Continued										
6B-8390	Medicine Creek at Maywood	A6	207	82	1951–59	May 20, 1951	[b]9.90	[a]2,120	25.9	314	6.8
8392	Elkhorn Canyon near Maywood	A6	6.74	6.74	1952–59	July 5, 1956	17.44	1,220	181	303	4.0
8394	Elkhorn Canyon southwest of Maywood.	A6	13.2	13.2	1952–59	...do	[a,e]27.2	8,660	656	864	10.0
8395	Brushy Creek near Maywood	A6	130	72	1906–59	June 21, 1947	[e]30.4	[a]70,000	972	2,590	27.0
8396	Frazier Creek near Maywood	A6	11.3	11.3	1952–59	July 5, 1956	[e,f]27.30	11,200	991	972	11.5
8397	Frazier Creek tributary near Maywood.	A6	.72	.72	1952–59	...do	11.53	483	671	162	3.0
						July 20, 1958	[d]12.33	------	------	------	------
8398.5	Fox Creek north of Curtis	A6	13.8	13.8	1952–59	May 19, 1959	12.85	2,080	151	454	4.6
8399	Fox Creek above Cut Canyon near Curtis.	A6	31.8	31.8	1951–59	May 20, 1951	23.0	2,810	88.4	594	4.7
8399.5	Cut Canyon near Curtis	A6	25.6	25.6	1951–59	July 14, 1952	19.6	1,560	60.9	551	2.8
8400	Fox Creek at Curtis	A6	77	77	1947–58	June 21, 1947	[e]27.3	------	------	------	------
					1951–58	May 31, 1951	15.35	3,340	43.4	778	4.3
8405	Dry Creek near Curtis	A6	20	20	1947–58	June 21, 1947	[e]27.7	[m]25,900	1,300	940	27.6
8415	Mitchell Creek above Harry Strunk Lake.	A6	53	53	1888–1959	June 21, 1948	[e]28	------	------	------	------
					1950–59	May 20, 1951	17.35	5,230	98.7	983	5.3
8440	Muddy Creek at Arapahoe	A6	243	243	1947–59	June 22, 1947	[e]31	------	------	------	------
					1951–59	June 16, 1957	24.62	7,280	30.0	2,700	2.7
8500	Turkey Creek at Naponee	A3	138	138	1948–53	Sept. 20, 1950[n]	9.50	1,920	13.9	694	2.8
8502	Cottonwood Creek near Bloomington.	A3	15.6	15.6	1948–56	June 4, 1955	6.65	1,100	70.5	500	2.2
8510	Center Creek at Franklin	A3	146	57.4	1948–56	Sept. 20, 1950	[e,f]6.8	3,150	54.9	278	11.3
8511	West Branch Thompson Creek at Hildreth.	A3	27.4	27.4	1953–59	Aug. 15, 1958	13.93	1,290	47.1	398	3.2
8512	West Branch Thompson Creek near Hildreth.	A3	56.6	56.6	1953–59	June 15, 1957	18.35	1,670	29.5	407	4.1
8513	West Branch Thompson Creek tributary near Hildreth.	A3	13.9	13.9	1953–59	...do	18.20	907	65.3	324	2.8
8514	West Branch Thompson Creek near Upland.	A3	90.8	90.8	1953–59	...do	14.89	2,040	22.5	555	3.7

8515	Thompson Creek at Riverton-----	A3	223	223	1948–56	July 9, 1950	13.22	12,200	54.7	2,220	5.5
8520	Elm Creek at Amboy-------------	A3	39.2	39.2	1948–53	Sept. 20, 1950	9.45	3,860	98.5	964	4.0
8807.1	School Creek tributary near Harvard.	A3	13.1	13.1	1952–59	Sept. 6, 1958	12.14	164	12.5	104	1.6
8807.2	School Creek near Harvard -----	A3	55.1	55.1	1953–59	July 10, 1958	16.74	960	17.4	440	2.2
8807.3	School Creek tributary 2 near Harvard.	A3	14.0	14.0	1953–59	---do--------	16.17	510	36.4	213	2.4
8807.4	School Creek near Saronville ----	A3	89.4	89.4	1952–59	July 14, 1952	[e]17.6	1,280	14.3	888	1.4
8836	South Fork Big Sandy Creek near Edgar.	A3	15.2	15.2	1953–59	Aug. 16, 1957	13.56	595	39.1	185	3.2
8837	South Fork Big Sandy Creek near Davenport.	A3	32.0	32.0	1950,	July 9, 1950	[h]17.3	[a]1,400	43.8	352	4.0
					1952–59	------------	------	-------	------	------	------
8838	South Fork Big Sandy Creek near Carleton.	A3	49.4	49.4	1952–59	July 14, 1952	[e]16.4	1,740	35.2	629	2.8
8839	South Fork Big Sandy Creek near Hebron.	A3	81.9	81.9	1952–59	June 27, 1952	[e]21.8	3,160	38.6	1,520	2.1

[a]Approximate.
[b]Maximum observed.
[c]Approximate natural peak.
[d]Regulated peak; affected by backwater.
[e]From floodmark.
[f]Datum then in use.
[g]Adjusted for diversion.
[h]From information by local residents.
[j]Present site and datum.
[k]Exceeded by flood of Apr. 24, 1935.
[m]At site 2-3/4 miles upstream, from slope-area measurement.
[n]One of the greatest floods known occurred June 22, 1947; stage and discharge unknown.

Table 3.—*Unusual peak discharges at miscellaneous sites and at short-term gaging stations with contributing drainage area of 300 square miles or less*

Number	Stream and place of determination	Tributary to—	Flood region and hydrologic area	Drainage area (square miles)		Period of known floods	Maximum stage and discharge			
				Total	Contributing		Date	Gage height (feet)	Discharge	
									Cfs	Cfs per square mile
	White River basin									
6A-4433	Deep Creek near Glen, SE¼ sec. 32, T. 31 N., R. 53 W.	White River----	A7	10.9	10.9	1952–59	Aug. 15, 1953	16.42	3,050	280
	Niobrara River basin									
4562	Pebble Creek near Esther, NW¼ sec. 10, T. 30 N., R. 49 W.	Cottonwood Creek.	A7	3.07	3.07	1953–59	July 28, 1953	18.67	2,000	651
4631	Bone Creek tributary near Ainsworth, NW¼ sec. 17, T. 30 N., R. 22 W.	Long Pine Creek.	A4	.39	.39	1956–59	July 3, 1959	12.11	150	385
4632	Bone Creek tributary 2 near Ainsworth, SE¼ sec. 8, T. 30 N., R. 21 W.	---do----------	A4	2.18	2.18	1958–59	May 30, 1958	10.93	60	27.5
4633	Sand Draw tributary near Ainsworth, NW¼ sec. 6, T. 30 N., R. 22 W.	Bone Creek ----	A4	1.07	1.07	1956–59	July 3, 1959	12.54	126	118
	Platte River basin									
	Dead Horse Creek tributary at Loup City, SE¼ sec. 7, T. 15 N., R. 14 W.	Middle Loup River.	A4	3.2	3.2	-------	June 17, 1954	------	944	295
	Dead Horse Creek at Loup City, NW¼ sec. 17, T. 15 N., R. 14 W.	---do----------	A4	6.2	6.2	-------	---do--------	------	2,410	389
	Elm Creek near Fremont, SE¼ sec. 34, T. 17 N., R. 8 E.	Platte River----	A2	4.7	4.7	-------	Aug. 2, 1959	------	2,840	604
	Union Creek tributary near Madison, NW¼ sec. 8, T. 21 N., R. 1 W.	Elkhorn River---	A4	2.5	2.5	-------	June 2, 1950	------	2,560	1,024

	Union Creek at Madison, sec. 32, T. 22 N., R. 1 W.	---do----------	A4	167.0	167.0	1877–1950	June 1940	------	16,300	976
	Middle Logan Creek near Laurel, sec. 32, T. 29 N., R. 3 E.	Logan Creek ---	A1	37.5	37.5	--------	May 18, 1944	------	5,000	133
	East Fork Maple Creek near Howells, sec. 21, T. 20 N., R. 4 E.	Maple Creek ---	A4	67.1	67.1	--------	June 11, 1944	------	22,000	328
6B-8012	Olive Branch above Sprague, NW¼ sec. 5, T. 7 N., R. 6 E.	Salt Creek -----	A2	43	43	1956–59	Aug. 18, 1956	17.46	1,670	38.8
8013.2	Olive Branch below Sprague, SW¼ sec. 23, T. 8 N., R. 6 E.	---do----------	A2	81	81	1956–59	July 10, 1958	16.02	4,380	54.1
	Middle Creek at Emerald, SE¼ sec. 23, T. 10 N., R. 5 E.	---do----------	A2	88	88	1909–53	June 2, 1951	------	6,700	76.1
8032	Antelope Creek at 48th St., Lincoln, SW¼ sec. 32, T. 10 N., R. 7 E.	---do----------	A2	6.82	6.82	1951, 1958–59	June 14, 1951	------	4,930	723
8033	Antelope Creek at 27th St., Lincoln, SE¼ sec. 25, T. 10 N., R. 6 E.	---do----------	A2	10.4	10.4	1957–59	July 10, 1958	12.8	2,550	245
8034	Antelope Creek at Lincoln, NW¼ sec. 24 T. 10 N., R. 6 E.	---do----------	A2	12.5	12.5	1958–59	---do--------	11.99	2,800	224
	North Fork Cottonwood Creek near Prague between sec. 26 and 35, T. 16 N., R. 5E.	Cottonwood Creek.	A2	5.2	5.2	1909–59	Aug. 2, 1959	------	4,780	919
	Kansas River basin									
8375	Red Willow Creek near McCook, NW¼ sec. 6, T. 4 N., R. 29 W.	Republican River.	A7	600	300	1935, 1941–47	June 1, 1935	[a]23.9	[b]45,000	150
						1958–59	-------------	------	-------	------
	Brushy Creek near Maywood, sec. 34, T. 8 N., R. 29 W.	Medicine Creek	A6	163	105	1874–1959	June 21, 1947	------	90,000	857
	Medicine Creek near Curtis, sec. 35, T. 8 N., R. 28 W.	Republican River.	A6	358	290	-------	June 21, 1947	------	83,000	286
8398	Fox Creek tributary near Curtis, NE¼ sec. 9, T. 10 N., R. 28 W.	Medicine Creek.	A6	6.97	6.97	1952–59	May 19, 1959	12.83	2,980	428
	Unnamed Creek at McCool Junction, NE¼ sec. 13, T. 9 N., R. 3 W.	West Fork Big Blue River.	A3	17.2	17.2	-------	July 9, 1950	------	15,200	884
	Unnamed Creek near York, center sec. 6, T. 9 N., R. 2 W.	---do----------	A3	6.9	6.9	-------	---do--------	------	23,000	3,330

[a]Furnished by Corps of Engineers.

[b]Approximate.

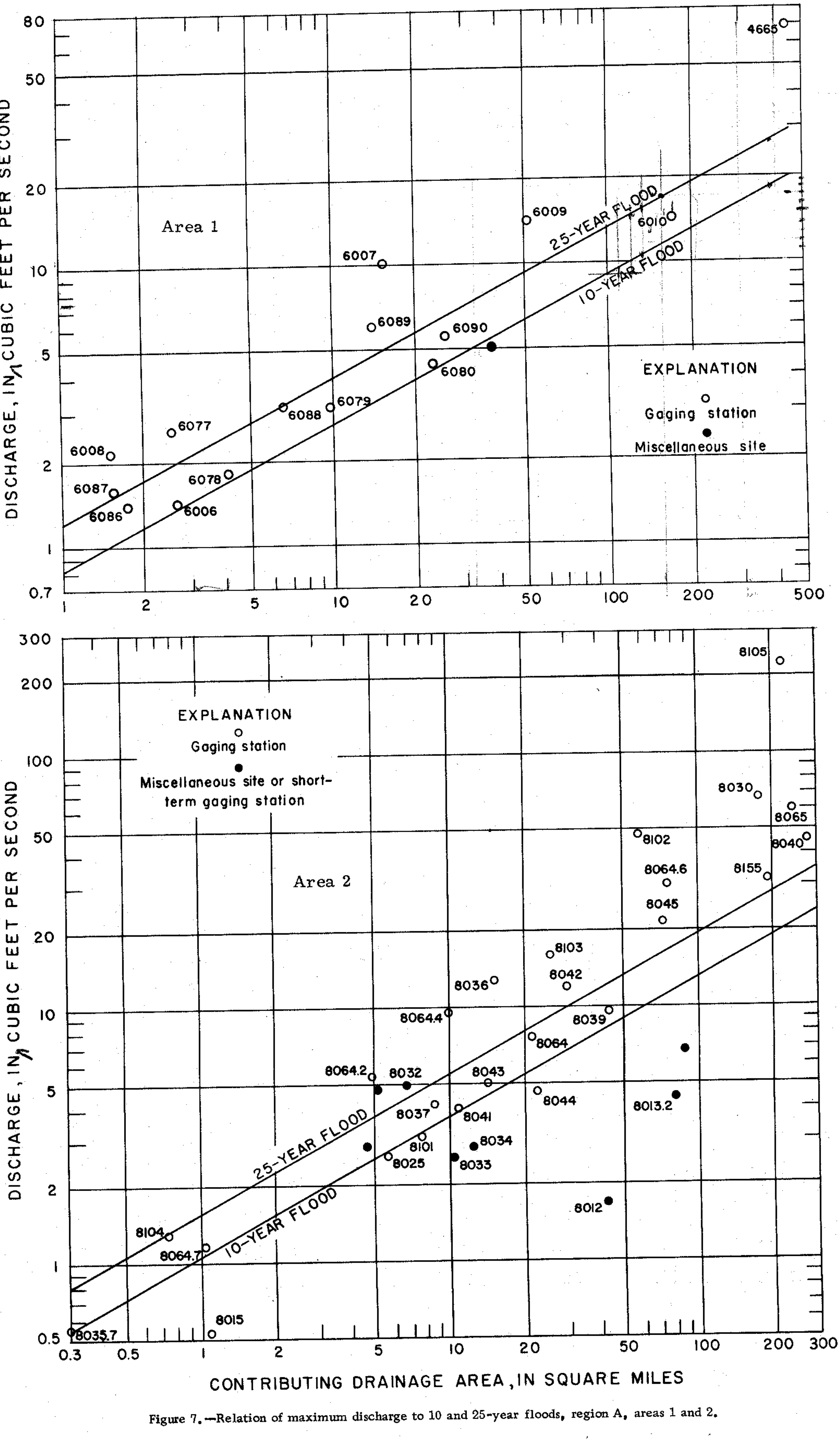


Figure 7.—Relation of maximum discharge to 10 and 25-year floods, region A, areas 1 and 2.

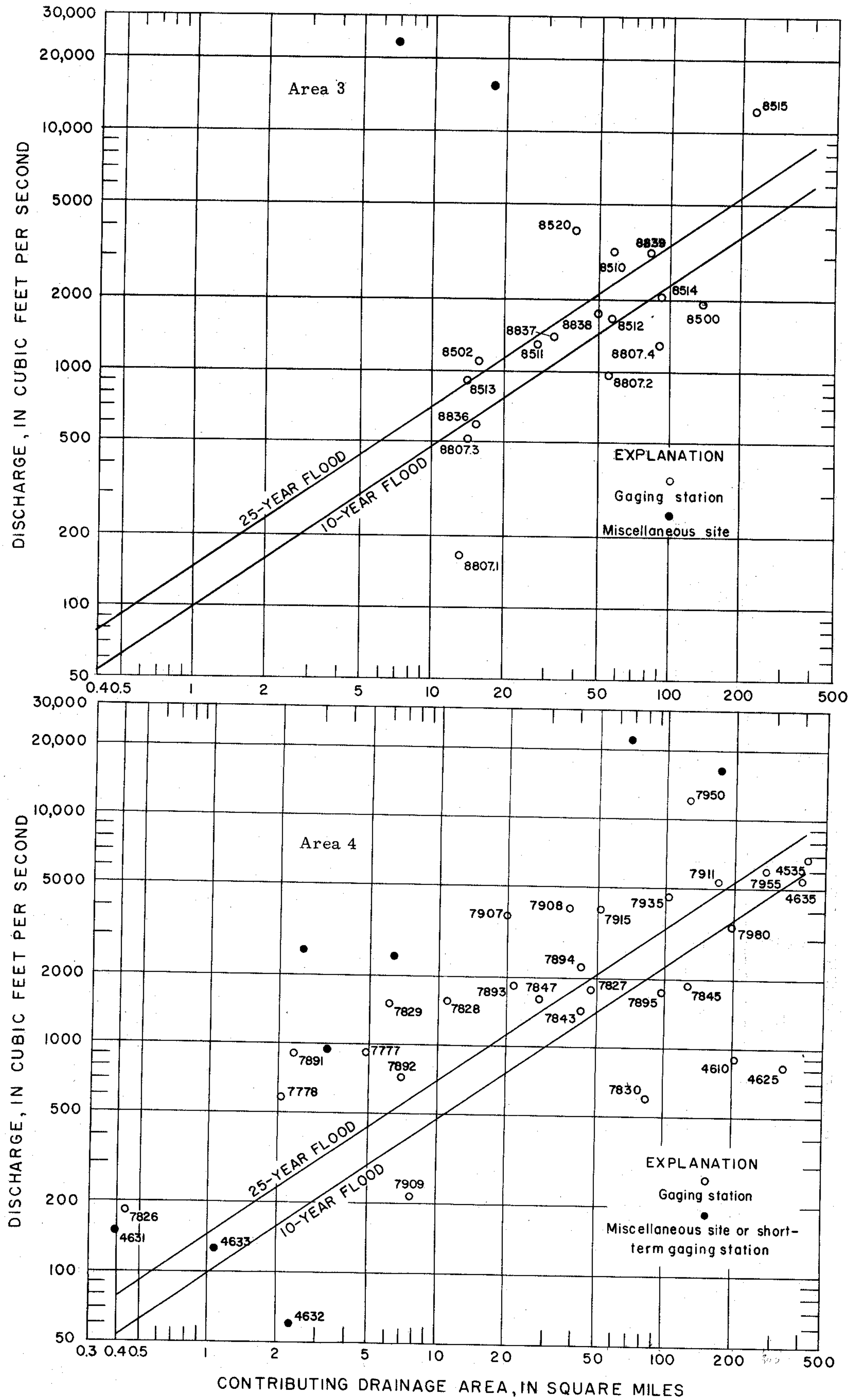


Figure 8.—Relation of maximum discharge to 10 and 25-year floods, region A, areas 3 and 4.

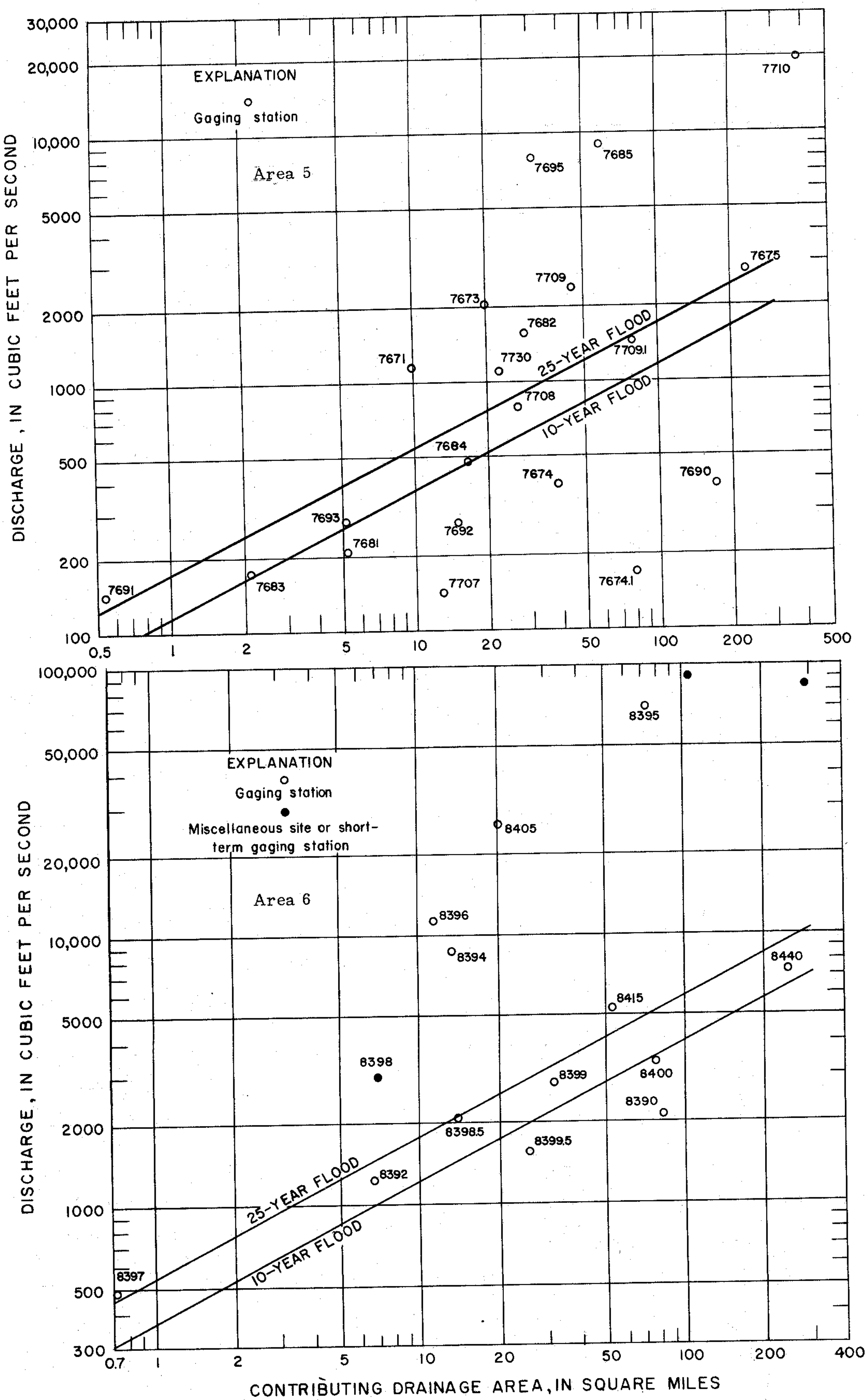


Figure 9.—Relation of maximum discharge to 10 and 25-year floods, region A, areas 5 and 6.

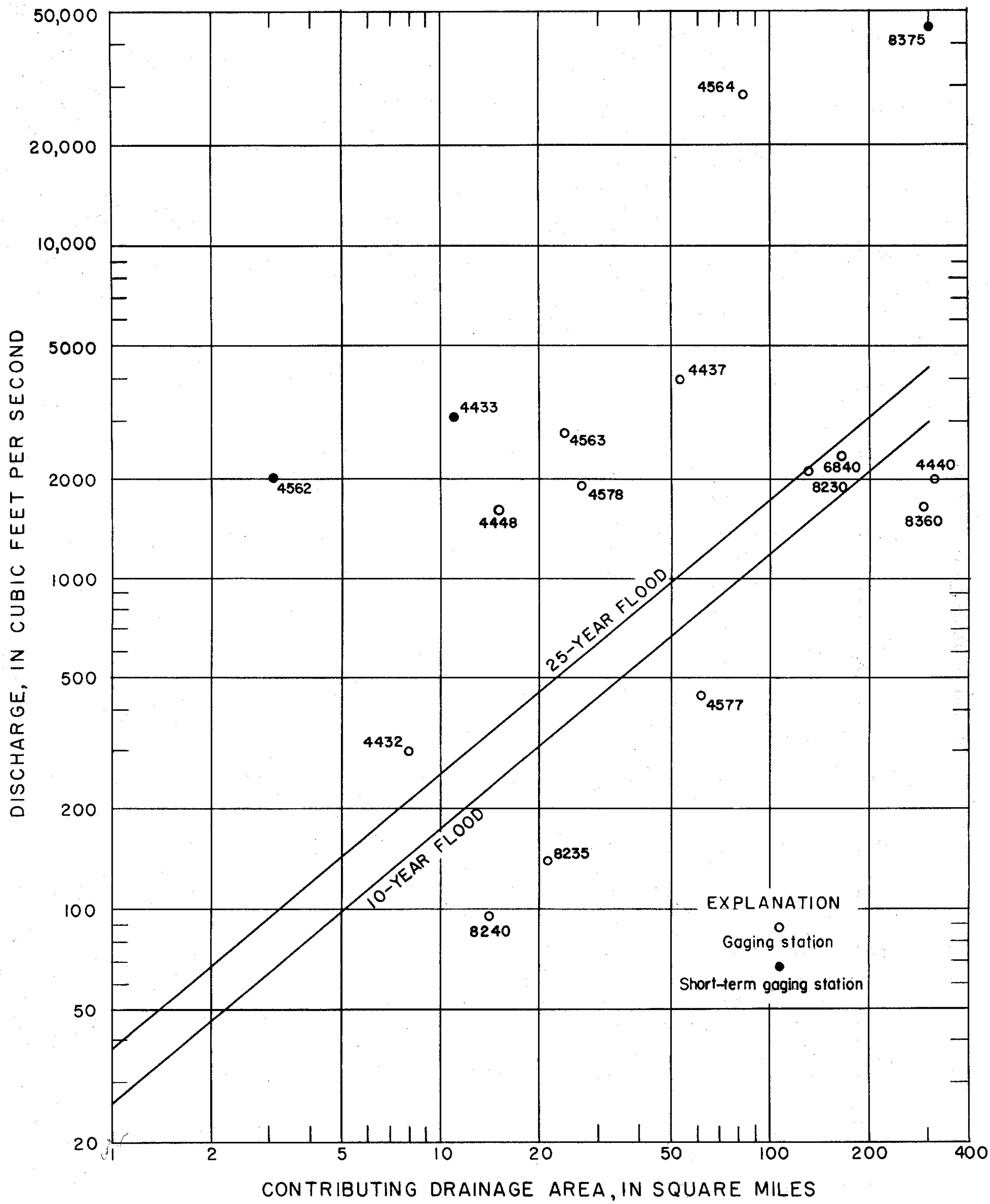


Figure 10.—Relation of maximum discharge to 10 and 25-year floods, region A, area 7.

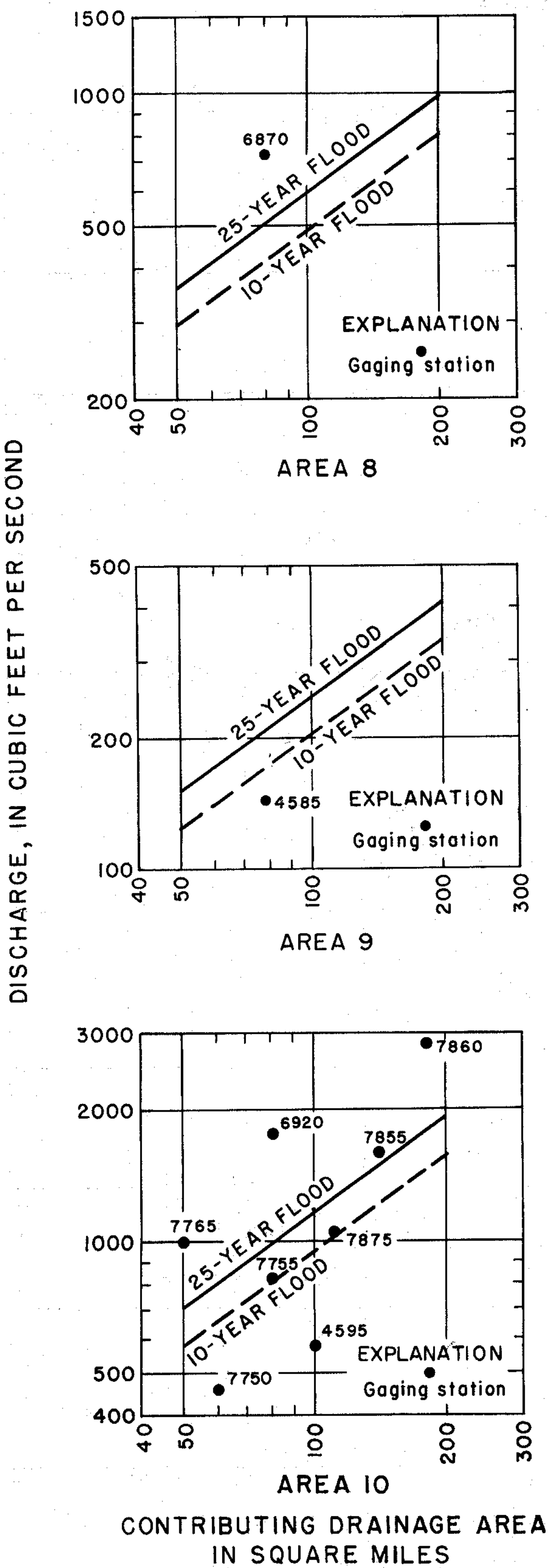


Figure 11.—Relation of maximum discharge to 10 and 25-year floods, region B, areas 8, 9 and 10.

SUMMARY

The accuracy of flood magnitudes for selected recurrence intervals obtained by methods outlined in this report is contingent upon the number of stations used, and the length of each record. When more data are obtained and, perhaps, improved methods of analysis are developed, better definition of the flood regime will be possible.

The curves presented are based on all available annual peak data through the 1959 water year on uncontrolled and unregulated streams having 300 square miles or less contributing drainage area, and 5 or more years' record of annual peaks. The regional frequency curves cannot be extrapolated with confidence beyond 25 years. The drainage area-mean annual flood curves should not be extended beyond the limits shown.

The curves presented in this report should not be used on controlled and regulated streams.

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